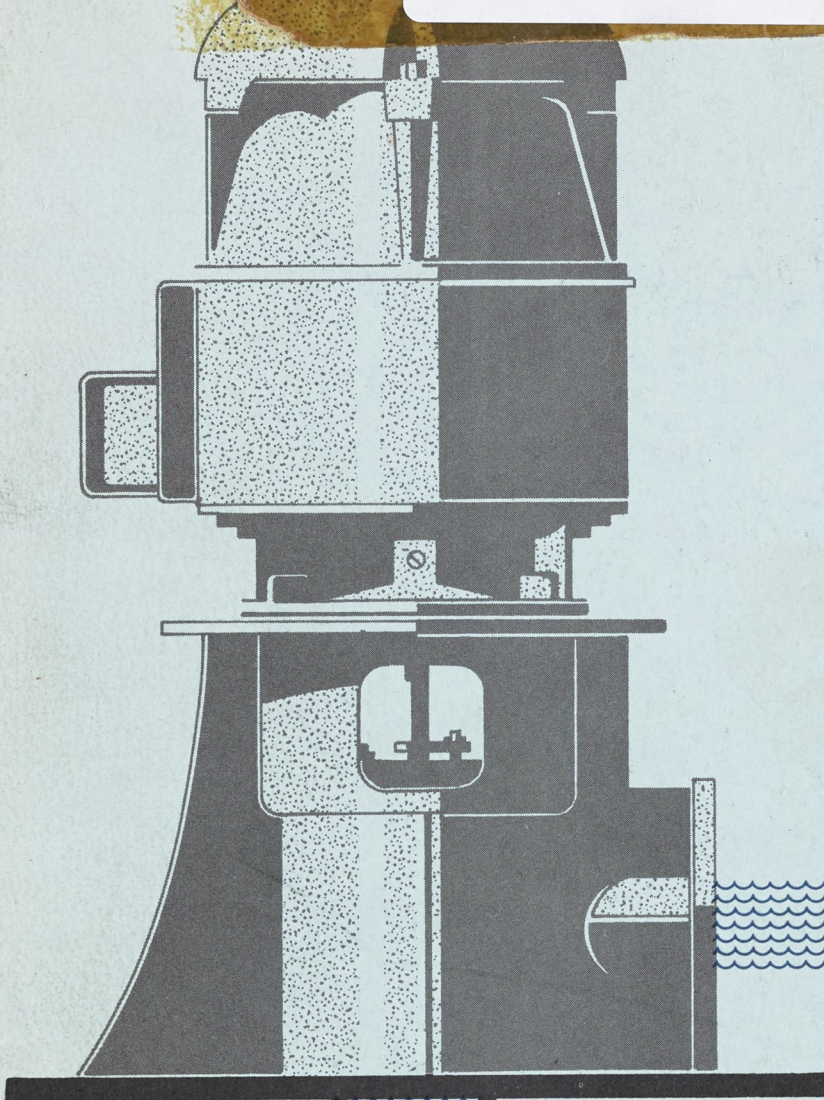


DCPL #46 Ground

DALY CITY



KIRKER, CHAPMAN & ASSOC.
446 Grand Avenue
South San Francisco, California

in conjunction with:

DAVID K. TODD, Ph. D
Consulting Hydrologist

Ground Water Investigation 1972

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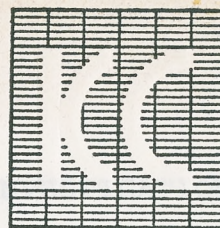
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Consulting Civil Engineers ■ Land Development Planning

April 1972

70-716

Daly City City Council
City of Daly City
Civic Center
333 90th Street
Daly City, California 94015

Gentlemen:

In accordance with our Agreement for Professional Services with respect to the Water Conservation and Well Yield Study dated September, 1970, we are submitting herewith our report entitled "Daly City Ground Water Investigation".

The report confirms that which was previously only a suspicion -- namely, that a very serious overdraft does exist. The safe yield of the portion of the aquifer directly tributary to the Daly City wells is approximately 11 percent of current pumpage. The safe yield of the entire aquifer is approximately 45 percent of the total current pumpage.

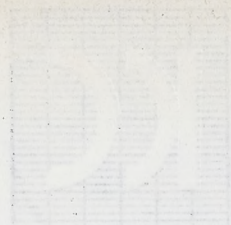
The City Engineer of Daly City, the Water Departments of Daly City and San Bruno, California Water Service Company, Pump Repair Service Company, and many other organizations and individuals have contributed to the background data essential to this report. We wish to acknowledge these contributions collectively and express our thanks and appreciation for their contributions.

It has been a distinct pleasure to work with the City Council and the various departments of the City. We look forward to serving your future engineering needs.

Very truly yours,

KIRKER, CHAPMAN & ASSOCIATES
Consulting Civil Engineers

W.E. Chapman
William E. Chapman
Vice President



KIRKKE, CHAPMAN & ASSOCIATES
Consulting Civil Engineers - Land Development Planning

70-776

April 1972

Daily City Council
City of Daily City
Civic Center
233 South Street
Daily City, California 94015

Gentlemen:

In accordance with our Agreement for Professional Services with respect to the Water Conservation and Well Yield Study dated September, 1970, we are submitting herewith our report entitled "Daily City Ground Water Investigation".

The report confirms that which was previously only a suspicion, namely, that a very serious overdraft does exist. The safe yield of the portion of the aquifer directly tributary to the Daily City wells is approximately 11 percent of current pumping. The safe yield of the entire aquifer is approximately 45 percent of the total current pumping.

The City Engineer of Daily City, the Water Department of Daily City and San Bruno, California Water Service Company, Pump Repair Service Company, and many other organizations and individuals have contributed to the background data essential to this report. We wish to acknowledge these contributions collectively and express our thanks and appreciation for their contributions.

It has been a distinct pleasure to work with the City Council and the various departments of the City. We look forward to serving your future engineering needs.

Very truly yours,
Kirkker, Chapman & Associates

KIRKKE, CHAPMAN & ASSOCIATES
Consulting Civil Engineers

William E. Chapman
Vice President

DALY CITY GROUND WATER INVESTIGATION

FOR

THE CITY OF DALY CITY, CALIFORNIA

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Mr. J. N. Crowell, of the staff of Kirker, Chapman & Associates, served as Project Engineer in the preparation of the report.

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Many organizations and individuals have rendered valuable assistance in providing relevant information in connection with this study. Particular acknowledgment is due the following individuals:

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California Water Service
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INTRODUCTION

For over 50 years the City of Daly City has obtained a major portion of its water supply from ground water. For some time it has been noticed that the water extractions by Daly City and other adjoining users have caused water levels to recede, and thus concern has been raised over the continuing ability of that aquifer to supply water to Daly City. Moreover, the quality of water in some aspects has diminished. For these reasons, the City Council, on September 30, 1970, authorized the firm of Kirker, Chapman & Associates to investigate the hydrological aspects of this extremely important natural resource.

The report defines the geological extent of the aquifer and its tributary area of replenishment. It provides an inventory of existing wells and their aggregate capacity. Storage volume, recharge and safe yield are also determined. Current well pumpage is compared with the safe yield which, in turn, defines the magnitude of the overdraft. Ground water quality is studied and future ground water extractions are discussed. Detailed maps, graphs, sections, tables and tabulations are provided to explain, clarify and summarize the findings; and recommendations concerning future courses of action are given.

SUMMARY AND RECOMMENDATIONS

Continually declining water levels throughout northern San Mateo County have caused Daly City to suspect that the life of its ground water supply was limited. This report confirms that suspicion; moreover, the degree to which the ground water aquifer has been overdrawn is much worse than was previously suspected. The water table adjoining Daly City is being depressed at a rate of approximately six feet per year. Immediately surrounding Daly City, an average of 1,813 million gallons are being removed each year. This should be compared to a mean safe yield (that volume of water which may be extracted without harmful effects) of only 186 million gallons. Thus, this portion of the aquifer is overdrawn by approximately 900 percent. At the current rate of pumping it may be expected that this vital natural resource concentrated near Daly City will be essentially depleted within 10 to 15 years.

Although this study focused on the area immediately surrounding Daly City, the report did review the entire aquifer from within San Francisco to San Bruno. It is essential to note that the entire aquifer is hydraulically connected; nevertheless, the horizontal flows are extremely slow and must travel over great distances. For this reason the Daly City aquifer could be analyzed almost as a separate entity. But in treating the aquifer in its entirety it has been determined that it, too, is overdrawn. Specifically, the total pumpage from the entire

aquifer is 4,610 million gallons per year. The safe yield is only 2,050 million gallons per year, thus indicating that the overall aquifer is overdrawn in excess of 100 percent.

Although overdraft adjoining Daly City is excessive compared to the overdraft throughout the entire basin, this does not mean that only Daly City contributes to the aquifer's general depletion. The data included in this report indicate that other well concentrations in the aquifer, such as San Bruno, Colma, and South San Francisco, may be over-pumping to an extent comparable to Daly City. Nevertheless, these other specific areas were not the assignment of this study.

Any future land development would further prevent rain water from seeping into the ground to recharge the aquifer. This is seen in the fact that the placement of impervious surfaces over the ground, such as streets, roofs and storm drain systems inhibit seepage into the ground. Urbanization of the aquifer area during the period of 1970 - 1995 is expected to further reduce the natural recharge by about 8 percent which, for practical purposes, indicates that recharge will remain nearly constant. Ground water extractions are not expected to increase in the future, and they should not increase in view of the results of this report.

Water quality has also been a noticeable problem in Daly City and this was investigated. Analysis of samples of ground water pumped from Daly City wells show that the quality meets recommended limits of the U. S. Public Health Service, with the

exception of nitrates and phenols. These problems appear to be widespread within the local aquifer; therefore, it is doubtful that replacement wells could produce water of superior quality. The removal of these constituents would be extremely expensive and uneconomical. This is especially true in view of the expected short life or small volume which can safely be removed from the aquifer. Thus, the capital expenditure relative to removing both phenols and nitrates could not be easily retired by virtue of the small available water volumes treated by this expenditure. Continued dilution seems to be the best course of action in this regard.

In the past it has been suspected that Lake Merced provided some recharge to the ground water basin. This was found not to be true. A detailed water balance for Lake Merced, made possible in part by the accurate level and pumping records of San Francisco, revealed that there is a mean inflow of ground water into the lake amounting to approximately 223 million gallons per year. Thus, it was found that Lake Merced does not contribute to Daly City's ground water supply.

Alternate solutions to the problem were studied in detail. It was noted that well pumpers were forced to decrease their pumpage to save an aquifer in Southern California. This was forced upon the pumpers by court proceedings known as adjudication. This is known to be a time-consuming process and the remaining life of the Daly City aquifer does not permit the luxury of this extended process. Artificial recharge was

considered. This is the process of increasing the safe yield by artificially returning water to the aquifer by means of percolation ponds or injection wells. Percolation ponds although feasible in areas where land costs are low were found not economical in Daly City because of the extremely high land costs in combination with other costs. Injection wells also were found to be not economical. Desalination was briefly reviewed, but then discarded not only because of its extremely high cost, but also because once desalinated it would be better to pump this water directly into the water system rather than returning it to ground water.

The answer to the problem appears to be the use of alternate sources of water and withholding and preserving ground water use only for its highest and best use, namely domestic use. The North San Mateo County Sanitation District in a study entitled, "Waste Water Reclamation Study" indicated that its reclaimed sewage could be used for irrigation. If this plan were employed, it could relieve the aquifer from the demand which current golf courses, cemeteries and agricultural users place upon the aquifer. Still another alternate source is the use of San Francisco water. Unfortunately, both of these alternate sources are more expensive than ground water.

If the solution of the ground water problem is the partial substitution of a separate reclaimed water system where it can be used in combination with San Francisco water, then how can the present irrigation well users be motivated into employing

this plan? Currently, well water is the most inexpensive source of water. It is four to five times less expensive than either reclaimed water or San Francisco water. Thus, there must be a compelling reason for these ground water users to seek alternate sources of water to preserve ground water. It may be too much to hope that a patriotic spirit of conservation will suddenly embrace each of these users. It seems more likely that legal means must be sought to coerce irrigation well pumpers to use reclaimed waste water and/or San Francisco water. In reality there is no choice; to do otherwise will soon deplete the ground water resource and the well pumpers will then find themselves forced into using either reclaimed water or San Francisco water. The question is only a matter of time. However, to wait means the loss of a natural resource, a resource which, if preserved, can supply the northern part of the County with valuable water should the San Francisco system fail for a short period in some future calamity.

For Daly City to reduce its well pumpage to the safe yield is not without cost. The additional cost of substituting San Francisco water at current prices would be approximately \$225,000 per year.

It is, therefore, the recommendation of this report that a separate district be established to instigate legal actions towards the preservation of this aquifer. Although not limited to the following list, the manifold functions of the proposed District are partially listed as follows:

1. Establish its legal position and boundary as a political subdivision within the State of California and San Mateo County with the attendant powers necessary to effectuate the functions herein listed.
2. Plan for the economical means whereby alternate sources of water may meet existing and future water demands within the proposed District. These sources may include San Francisco water in combination with a separate pipe system for reclaimed sewage from North San Mateo County Sanitation District and/or the South San Francisco Treatment Plant.
3. Determine the means whereby the necessary facilities may be financed.
4. Construct, maintain and operate the required pumps, reservoirs and pipe lines.
5. Cause all well pumpers to reduce or stop current well pumping to a combined level which will approximate the safe yield so that the ground water resource can continue to supply water and also can aid in meeting emergency and peaking demands.
6. Attempt, through negotiations, to purchase water from San Francisco from several metered connections at a rate which assumes that all water passes through only one meter. This would reduce water cost because each separate metered volume would not be required to separately pay the high costs of the initial rate charges.

7. Determine the most economical ratio of volumes of San Francisco water, reclaimed sewage, and ground water which will satisfy the combined water demand. In this regard one must consider the demand charge for water imposed by San Francisco, the decreasing unit charge for San Francisco water as volumes increase, the safe yield of the aquifer, and the availability of sewage effluent at the plants. This analysis may indicate that the entire safe yield should be pumped only during high demand periods, while during the remainder of the year there would be no pumping.
8. Designate those wells which are in the best geological and geographical locations to supply ground water during major fires or those times when the San Francisco system may be temporarily out of order.

Certainly, meetings and discussions should be held immediately towards the establishment of such a District. If the aquifer is to be saved, delays will only compound the problem.

The first part of the paper discusses the importance of the water supply in the region. It is noted that the water supply is a critical factor in the development of the region. The second part of the paper discusses the various factors that affect the water supply. These factors include the climate, the topography, and the land use. The third part of the paper discusses the various methods that can be used to increase the water supply. These methods include the construction of dams, the construction of canals, and the use of artificial recharge. The fourth part of the paper discusses the various problems that are associated with the water supply. These problems include the pollution of the water supply, the depletion of the water supply, and the unequal distribution of the water supply. The fifth part of the paper discusses the various solutions that can be used to solve these problems. These solutions include the construction of dams, the construction of canals, and the use of artificial recharge. The sixth part of the paper discusses the various conclusions that can be drawn from the study. It is concluded that the water supply is a critical factor in the development of the region. It is also concluded that the water supply can be increased by the construction of dams, the construction of canals, and the use of artificial recharge. Finally, it is concluded that the water supply can be protected by the construction of dams, the construction of canals, and the use of artificial recharge.

SECTION A

GROUND WATER GEOLOGY

GEOGRAPHICAL SITUATION

The Daly City aquifer, situated in the southwestern portion of San Francisco City and County and in the northern portion of San Mateo County, is located in the valley between the northern limits of the Santa Cruz Mountains on the west and San Bruno Mountain on the east. The aquifer extends from the Sunset District of San Francisco southward to Lake Merced and Daly City, and thereafter southeasterly, including the towns of Colma and South San Francisco, to San Bruno and San Francisco Bay. The width of the aquifer varies from 1.5 to 2.5 miles, while the length approximates nine miles. The location of the aquifer at ground surface is shown in Figure A-1.

Although the Daly City aquifer is a clearly identifiable physical unit, it is actually contained within two drainage basins. To the north is the Lake Merced Basin, which drains into the Pacific Ocean; and to the south the Colma Creek Basin drains into San Francisco Bay. The drainage divide occurs near the center of the aquifer in the vicinity of Daly City.

Because the aquifer consists of old marine deposits, the topography of the aquifer area is relatively low and uniform. The area slopes westward toward the Pacific Ocean in the northern portion, changing gradually to a shallow trough in the central area where it is contained by the adjacent mountains,

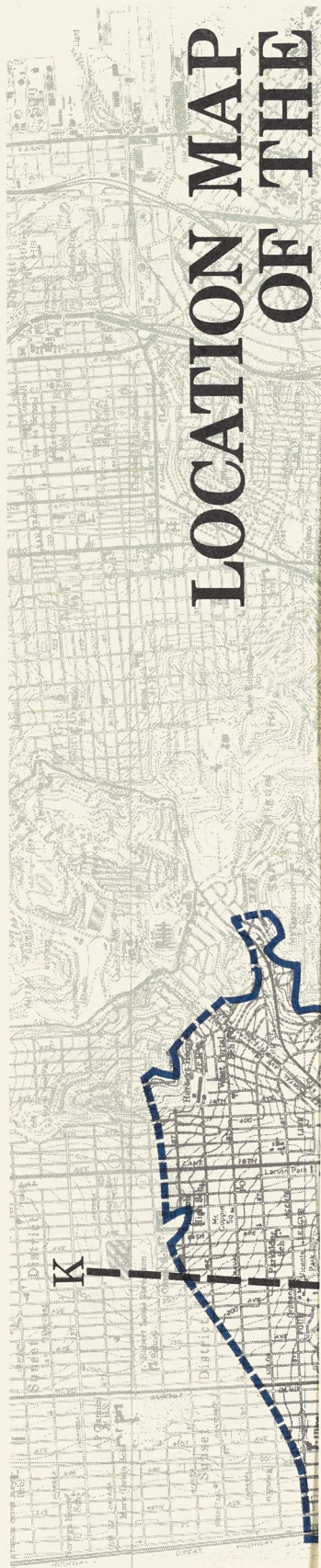
and in the southern region becoming an even shallower trough in the floodplain area of Colma Creek. Elevations range up to 400 feet MSL along the eastern edge of the aquifer but rarely reach more than 300 feet MSL on the western side. In the central trough of the valley, ground surface elevations approach sea level at the two ends of the aquifer and rise to 190 feet MSL at the drainage divide in the center of the aquifer.

DALY CITY AQUIFER

From a geological standpoint the Daly City aquifer as defined here consists of the Colma and Merced formations. Shallow dune sand supplements the aquifer to a minor extent in the area north of Lake Merced. The Colma formation is a stratified marine deposit of unconsolidated sand with some silt and clay. The Merced formation is an older marine deposit consisting of strata of sand, silt, and clay.

The lateral boundary of the aquifer to the northeast is the Franciscan group, a thick-bedded and massive sandstone interbedded with shale and conglomerate lenses, and containing chert, intrusive rocks, and metamorphic rocks. The boundaries to the southwest and beneath the aquifer are formed by the strata of the Merced formation, and because of the great thickness of this formation, no clearly defined aquifer limits can be specified.

Permeable boundaries through which water can move laterally into and from the aquifer are shown by dashed lines in Figure A-1. The northern end of the aquifer is thus delineated by the Pacific



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LOCATION MAP OF THE DALY CITY AQUIFER

The map displays the Daly City Aquifer boundary, which is outlined in solid blue. The boundary is irregular, following the coastline of Lake Merced and extending inland through the city. A grid of dashed lines, labeled A through K and 1 through 11, is overlaid on the map to indicate specific locations. The map also shows the San Francisco Bay, the Golden Gate Bridge, and various landmarks such as the San Francisco Golf Club, Lake Merced, and the San Francisco Peninsula. A north arrow and a graphic scale in feet (0 to 4000) are located in the bottom right corner.

FIGURE A-1



Ocean to the west, and the drainage divide of the Lake Merced watershed to the north. On the east side of the aquifer along the alignment of Alemany Boulevard, a bedrock valley in the Franciscan group permits ground water to drain westward into the aquifer even though surface drainage flows eastward.

At the southeastern end of the aquifer San Francisco Bay forms an eastern permeable boundary as do the drainage divides of the Colma Creek watershed to the north and south. It should be noted that the aquifer continues southeastward along the western shore of San Francisco Bay, including the coastal portions of San Bruno and Millbrae; however, it is believed that ground water in these areas acts essentially independently of ground water in the Daly City aquifer (See Figure A-1) because the natural flow is primarily toward the Bay and hence, perpendicular to the major axis of the aquifer.

The aquifer is essentially unconfined; nevertheless, in the lower zones the possibility of confined conditions exists resulting from the impermeable clay strata of the Merced formation. The aquifer has an average width of about 8,000 feet. The depth along the centerline of the valley ranges from -400 feet MSL to -600 feet MSL based upon depths of productive wells, but there are possibilities of permeable strata below these elevations. Along the northeast side, the aquifer thins as the Colma and Merced formations terminate against the steeply rising Franciscan group.



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GEOLOGICAL FORMATIONS

In the following sub-sections, brief geological descriptions of the various formations which constitute and bound the Daly City aquifer are given.

Colma Formation. The Colma formation is of Pleistocene Age and occurs primarily in the valley extending from Lake Merced to San Bruno. It lies unconformably on the Franciscan group and the Merced formation and is unconformably overlain by shallow deposits of alluvium, dune sand, and bay mud. The total thickness is not known, but it is believed not to exceed 200 to 300 feet.

In the northwest and central parts of the aquifer, the formation consists of friable well-sorted fine to medium sand containing a few beds of sandy silt, clay, and gravel; in the southeastern area the formation is mostly sandy clay and silty sand. Colors range from yellowish-orange in outcrops to gray where it is not weathered. Typically, the Colma formation is horizontally stratified and cross-stratified with most of the strata being laminated or thin-bedded.

Most of the Colma formation is sand, but some of it is silty sand and sandy silt. Occasionally, there are thin clay beds and gravel beds. The sand tends to be clean, well-sorted, subrounded, and fine to medium grained. Some of the silt and clay is an admixture with sand, forming beds of silty or clayey sand ranging in thickness from a few inches to several feet;

elsewhere the beds of silt and clay are fairly pure and contain only a small amount of sand. Some beds appear to be tabular and of uniform thickness, whereas others are lenticular and pinch out within a few tens of feet or a few hundred feet. The proportion of silt and clay in the Colma formation seems to be greater in the center of the valley than along the sides, and also greater to the southeast as compared with the northwest.

The Colma formation is more firm and coherent near the surface where it is weathered than at depth where it is fresher. Fresh sand in the formation has little or no cementing material; it is very friable, even loose in places, gullies rather easily, and requires supports in excavations. Weathering extends downward from the surface for an average of perhaps 15 to 20 feet.

Merced Formation. The Merced formation appears as a belt extending diagonally southeastward from Lake Merced across the San Francisco Peninsula. On the Pacific Ocean side the formation has a depth of approximately 5,000 feet. It overlies the Franciscan group unconformably and is unconformably overlain by the Colma formation.

The Merced formation consists of friable to firm sand, silt, and clay with minor amounts of gravel, lignite, and volcanic ash. In places the silt and clay are indurated to the extent that they are difficult to excavate with light power tools such as trenching machines. The sand is medium gray where fresh and yellowish-gray to yellowish-orange where weathered. The silt

and clay are medium or dark gray where fresh, and yellowish-orange, light gray, or grayish-orange where weathered.

Stratification is moderately distinct in most places. Many of the strata pinch out within a few hundred feet, while the gravel strata extend for only a few tens of feet. Most strata in the sand units of the Merced formation are less than one foot thick. In the Westlake area the Merced formation has a larger proportion of sand than the formation as a whole, and, therefore, closely resembles the Colma formation.

Zones of silt and clay are interlayered with sand. The thickness of the silt and clay zones ranges from about 50 to 200 feet. The silt and clay are relatively impermeable compared to the sand so that ground water tends to travel in the sand at the contact with the silt and clay. Within the sand there are a few clay zones 20 feet thick or less. Most of the clay in these zones is tough and plastic.

Dune Sand. Dune sand, overlying most of the aquifer to the north of Lake Merced, varies in thickness from place to place with maxima approaching 100 feet. The sand in general is gray, fine to medium grained, well sorted, and loose in most places. Most sand grains are subround or subangular, and polished surfaces predominate. Quartz, feldspar, and chert in varying proportions make up 90 to 95 percent of the dune sand.

Franciscan Group. San Bruno Mountain is a massive outcrop of the Franciscan group. These rocks are the oldest in the area, dating from the Jurassic and Cretaceous Ages, and are composed of a mixture of various types of rocks. Predominately, the group consists of an interbedded sandstone and shale which is hard, where fresh and intact, but soft where weathered or sheared. Commonly, the rocks are medium dark gray in color where fresh, olive gray to yellowish-brown where moderately weathered, and yellowish-orange to yellowish-gray where highly weathered. Also found in the Franciscan group are interbedded chert, volcanic rocks such as basalt, intrusive serpentine, and metamorphic rocks. Near the edges of the outcrop, small to large fragments of hard rock occur in a matrix of sheared rock.

Slope Debris and Ravine Fill. Along the lateral boundaries of the aquifer are found local deposits of slope debris and ravine fill originating from the Merced formation and the Franciscan group. Typically, these include stony silty to sandy clay and silty to clayey sand or gravel. The material is commonly yellowish-orange to medium gray and is unstratified to poorly stratified.

Recent Alluvium. Small thin surficial deposits of Recent alluvium occur at scattered locations in the aquifer area. The deposits tend to be long and narrow along streams or triangular behind artificial barriers. Because the Recent alluvium is derived principally from the Merced and Colma formations, it

consists mostly of poorly sorted sand, silt, and clay.

Artificial Fill. Artificial fill is built for a definite purpose, hence the material for most planned fills is carefully selected. In Westlake, for example, planned fill covers broad areas and ranges in thickness up to 70 feet. Fill material is usually obtained locally so that sand, silt, and clay from the Merced and Colma formations are principal constituents in the aquifer area.

GEOLOGICAL FAULTS

Early geological maps show the San Bruno fault running longitudinally through the valley from Lake Merced to San Bruno. The location of the fault is postulated from evidence of a shear zone within the older rocks along the southwest side of San Bruno Mountain. However, recent investigators have expressed the opinion that the location, displacement, and nature of the San Bruno fault are uncertain. Also, there is no indication of the fault extending up through the younger Colma formation; consequently, the fault appears to have little influence on the movement of ground water within the aquifer, except perhaps for deeper zones within the Merced formation to the east of the fault.

All other faults in the general vicinity lie outside the area of the Daly City aquifer.

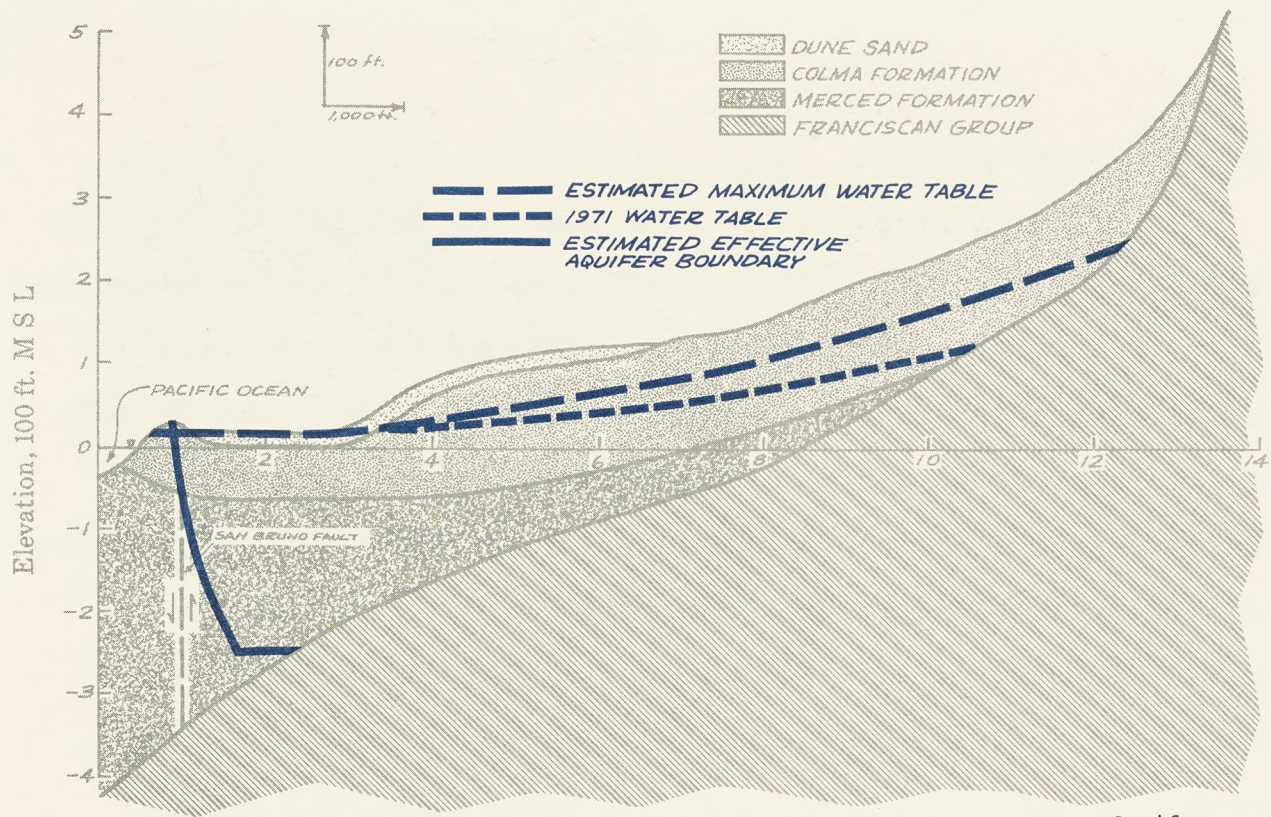
AQUIFER CROSS-SECTIONS

Ten lateral cross-sections through the aquifer are plotted in Figures A-2 through A-11 and the locations of the sections are identified by letters A through J in Figure A-1. The cross-sections show the aquifer and major bounding formations as well as the presumed location of the San Bruno fault. Local surficial deposits of Recent alluvium and artificial fill have been omitted as in almost all instances these materials occur well above the water table. Similarly, local occurrences of slope debris and ravine fill along the edges of the aquifer are not shown.

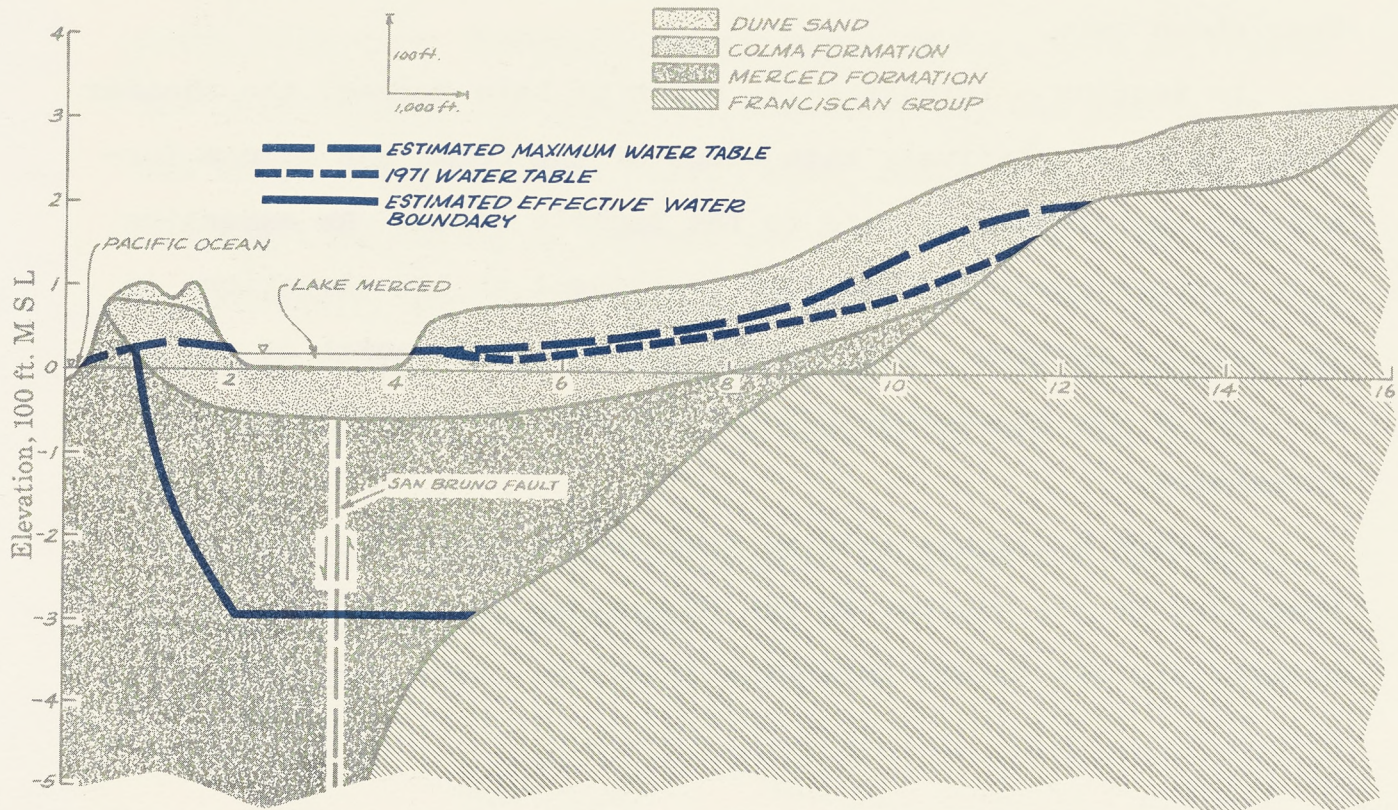
It should be noted that the vertical scales in Figures A-2 through A-11 have been exaggerated by a factor of ten for convenience; hence the aquifer in reality is much wider and thinner than shown here.

In Section A (Figure A-2), north of Lake Merced, the aquifer consists of a relatively thin wedge of the Colma and Merced formations and slopes westward to the Pacific Ocean. An extensive thin surface layer of dune sand is present at low elevations in the western portion. The aquifer thins rapidly north of this section as the Franciscan group rises and the Merced formation terminates.

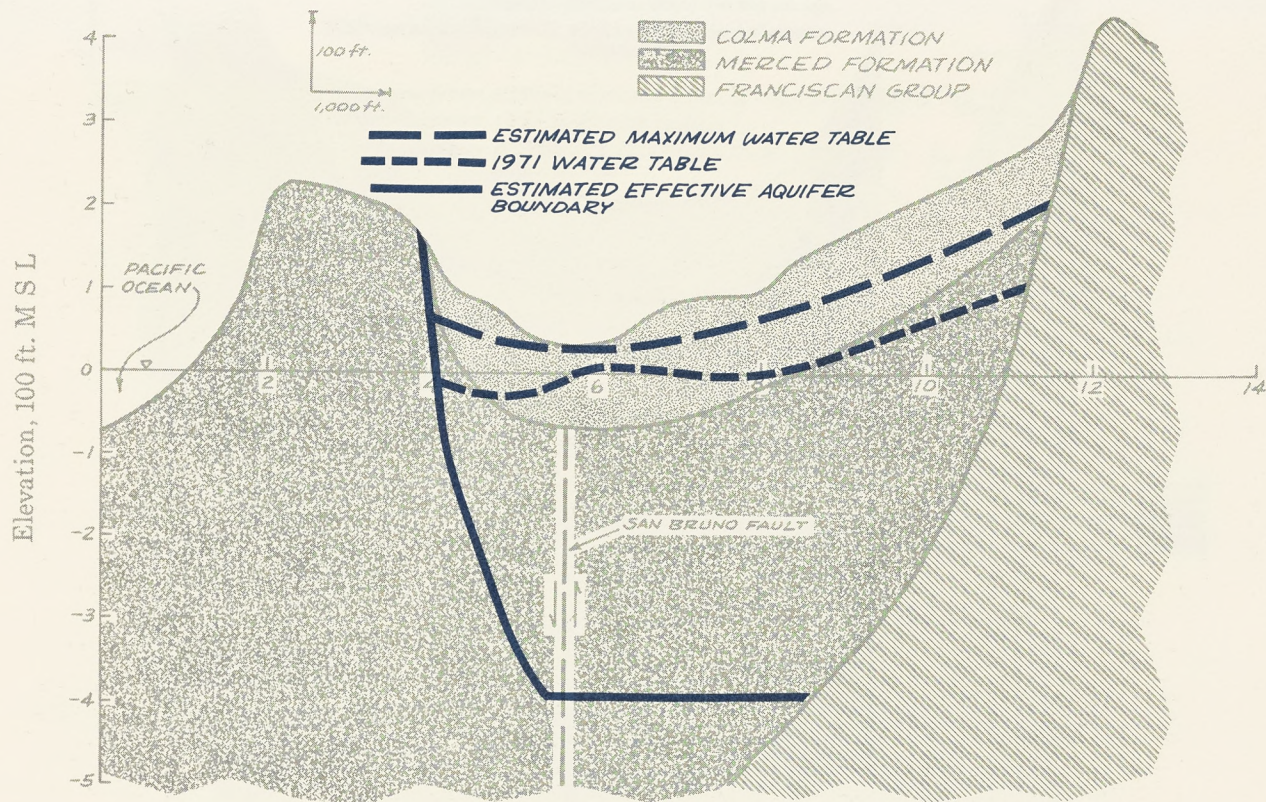
Section B (Figure A-3) at Lake Merced shows a pronounced deepening of the aquifer as the Franciscan group drops more steeply and the Merced formation thickens. Lake Merced is



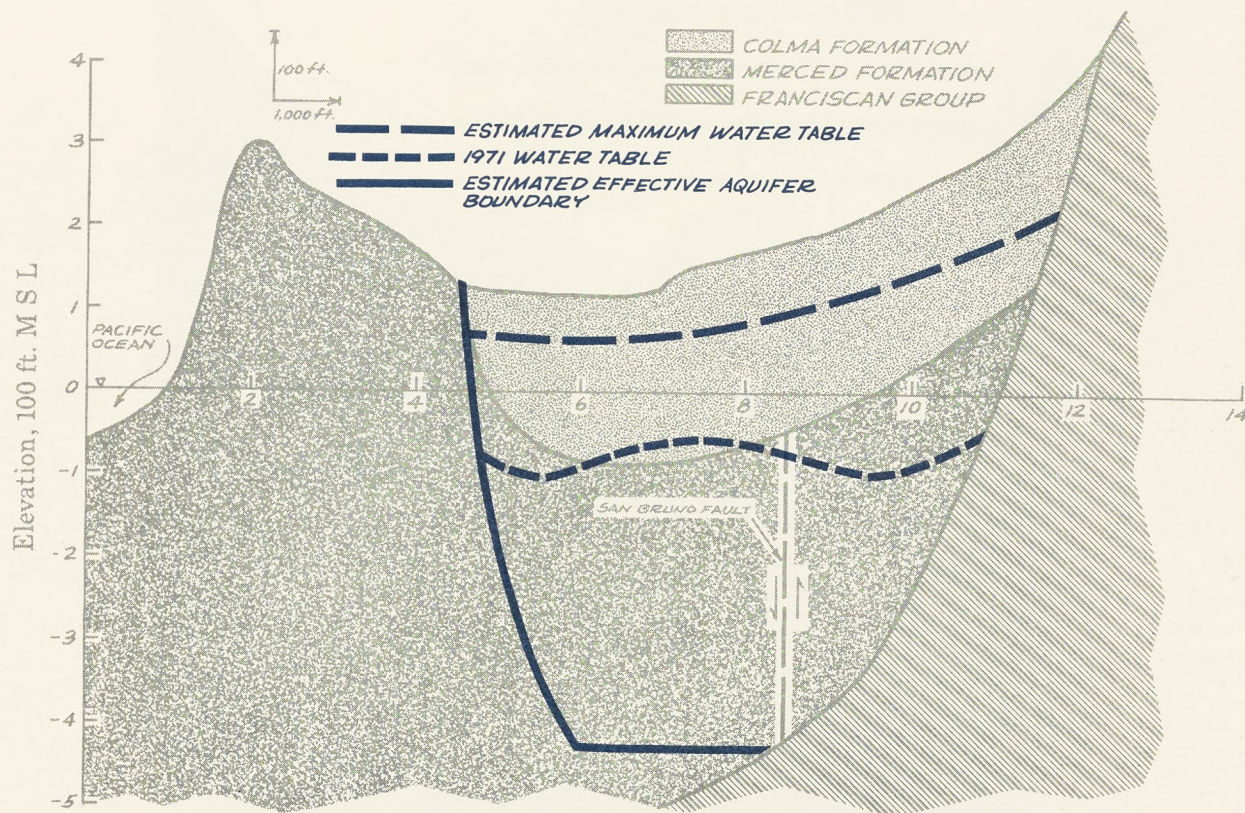
Aquifer
Section A
Figure A-2



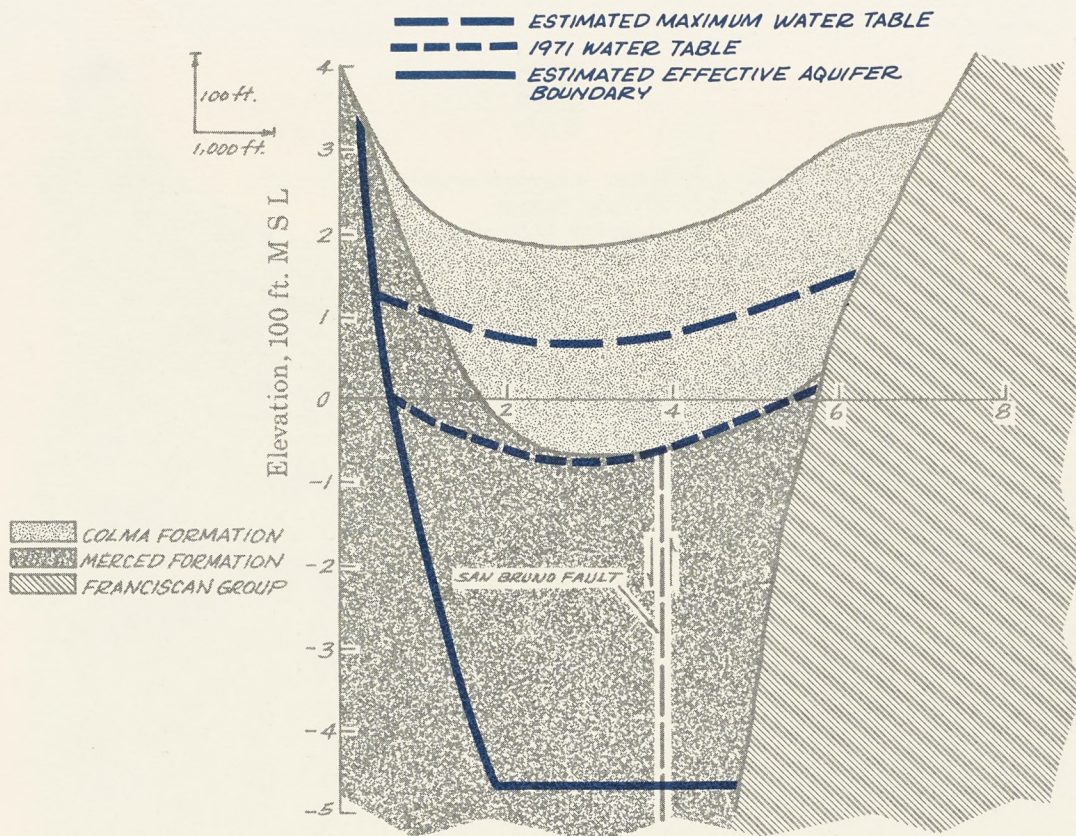
Aquifer
Section B
Figure A-3



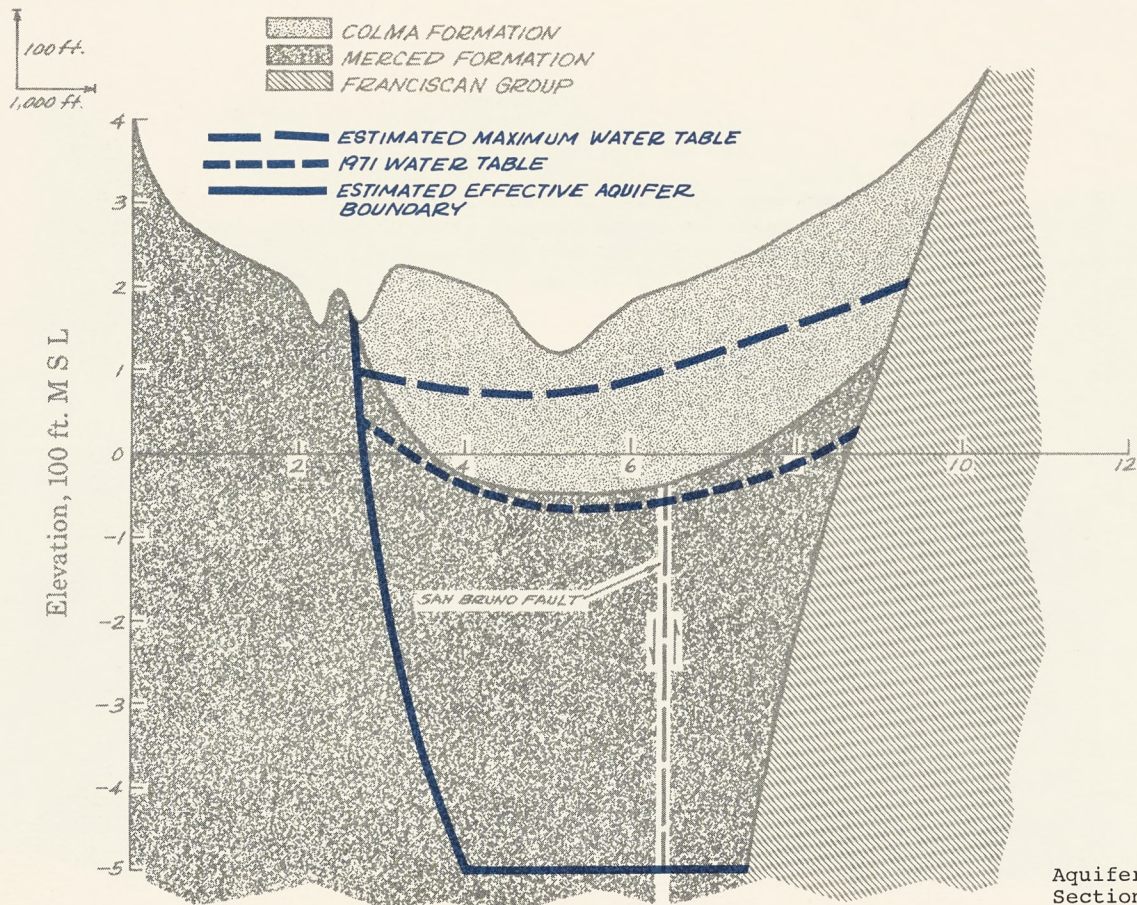
Aquifer
Section C
Figure A-4



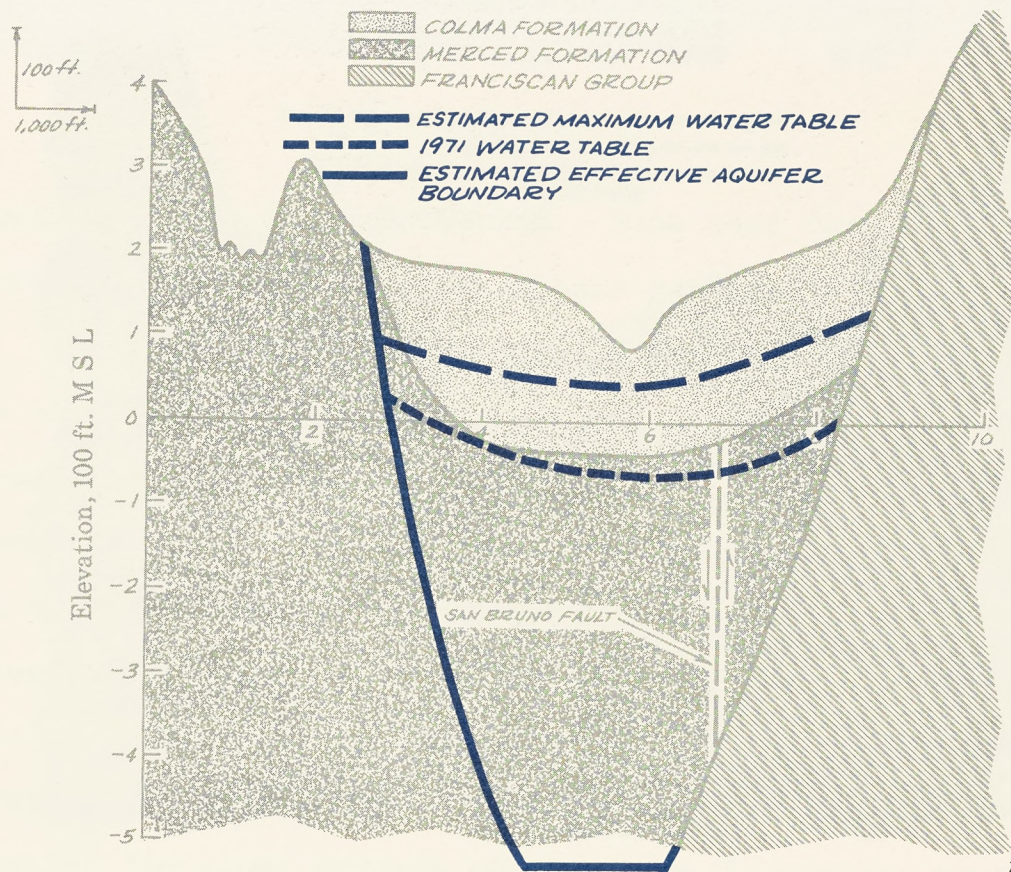
Aquifer
Section D
Figure A-5



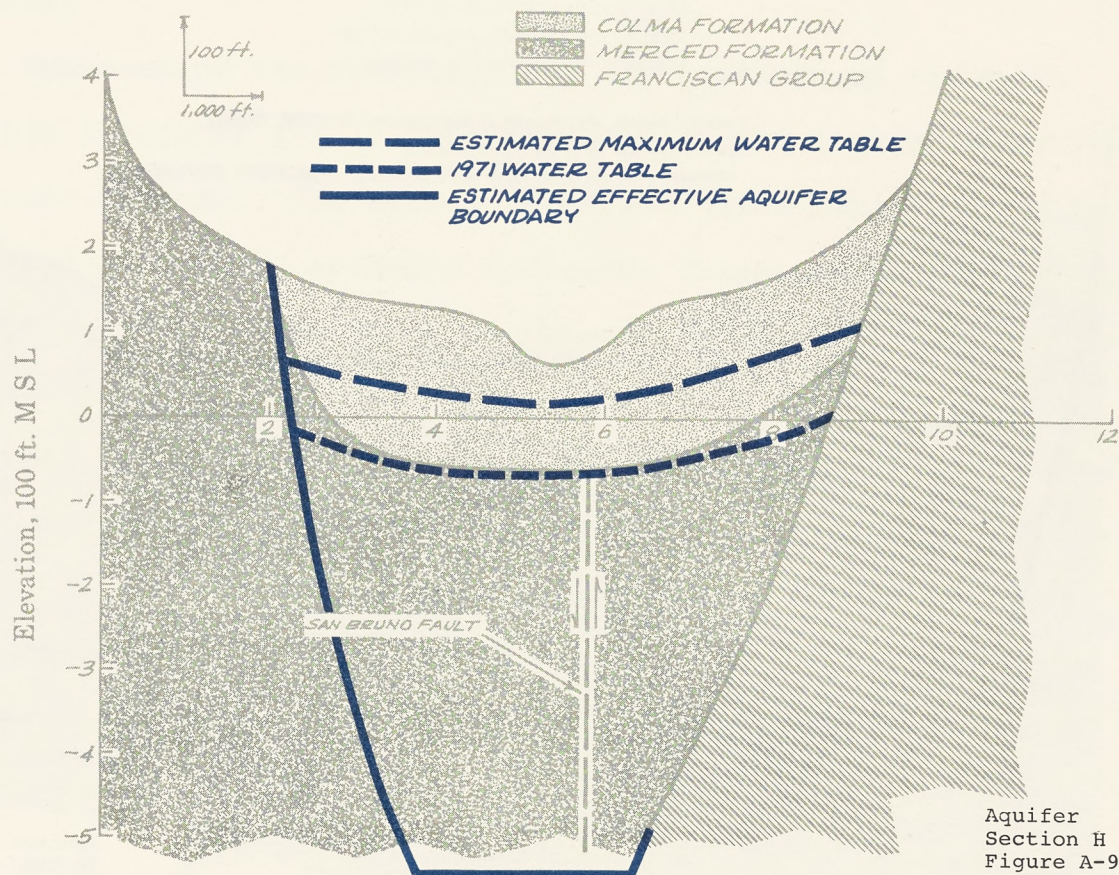
Aquifer
Section E
Figure A-6



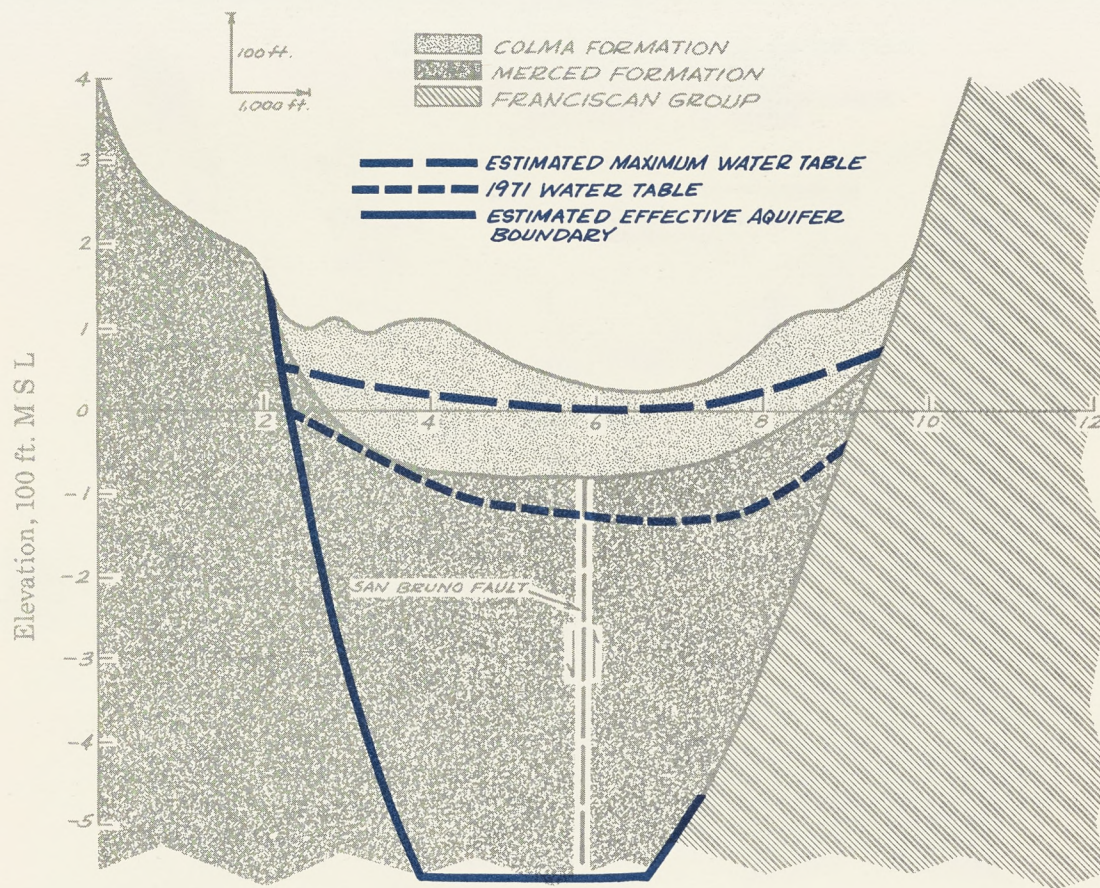
Aquifer
Section F
Figure A-7



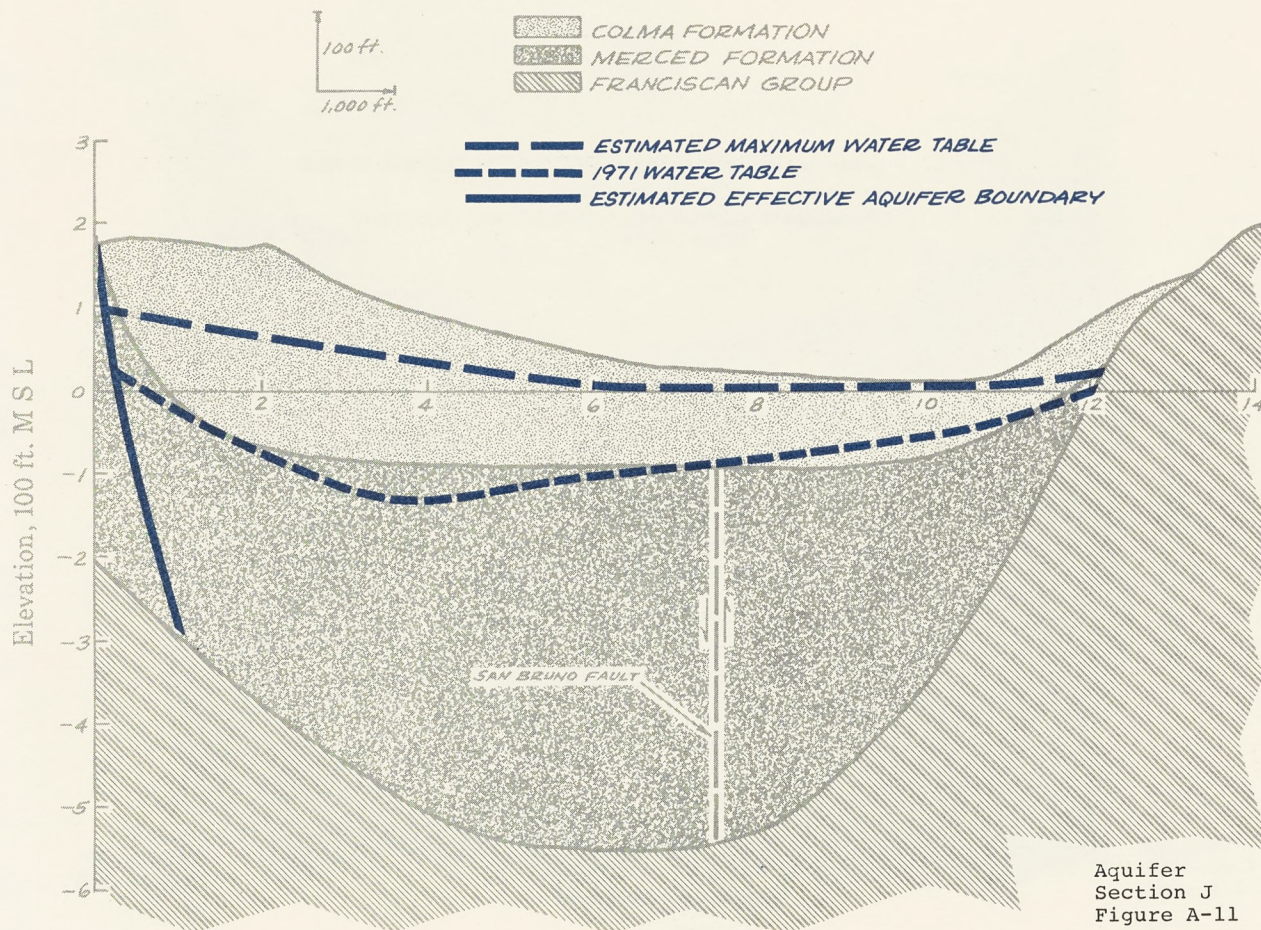
Aquifer
Section G
Figure A-8



Aquifer
Section H
Figure A-9



Aquifer
Section I
Figure A-10



Aquifer
Section J
Figure A-11

embedded in the Colma formation. Dune sand forms only a minor surficial layer to the west of Lake Merced.

The Sections C to I (Figures A-4 through A-10) encompass the bulk of the aquifer and show the typical U-shaped Colma formation underlain by the Merced formation. In all cases the Franciscan group drops sharply from its surface exposure along the northeast side of the aquifer, while the Merced formation extends from ground surface in the Santa Cruz Mountains to the west to depths of thousands of feet. The general orientation of the stratigraphy of the Merced formation is believed to parallel the lower surface of the Colma formation; thus, the strata are predominately horizontal in the trough of the valley and steepen to a nearly vertical angle in the outcrop area to the west.

Approaching San Francisco Bay, the aquifer, as shown in Section J (Figure A-11), becomes wider as the lateral mountain barriers diverge. The Merced formation thins rapidly in this area and geological evidence indicates a subsurface rise of the downfolded Franciscan group on the western side of the section.

To complete the three-dimensional view of the aquifer Figure A-12 shows a longitudinal geological cross-section, Section K, of the aquifer which is located also in Figure A-1. Here the vertical scale has been exaggerated by a factor of 40 to show clearly the topography. The topographical divide which separates the Lake Merced and Colma Creek drainage basins is

————— ESTIMATED MAXIMUM WATER TABLE
 - - - - - 1971 WATER TABLE
 ————— ESTIMATED EFFECTIVE AQUIFER BOUNDARY

DUNE SAND
 COLMA FORMATION
 MERCED FORMATION
 FRANCISCAN GROUP



Figure A-12
 Longitudinal
 Section of
 the Aquifer

clearly revealed in the vicinity of Daly City.

It can be seen in Figure A-12 that the aquifer consists of an insignificantly thin layer of dune sand and Colma formation to the north of Pine Lake Park, where the Franciscan group approaches ground surface. In the central portion of the aquifer the Merced formation has a nearly horizontal top surface near -50 feet MSL to -100 feet MSL and extends to great depths. Finally, near the southeastern end of the aquifer the Merced formation thins and the underlying Franciscan group rises toward San Francisco Bay.

PHYSICAL CHARACTERISTICS OF THE AQUIFER

Based upon soil test and well log data, physical properties of the geological materials forming or associated with the Daly City aquifer are summarized in Table A-1. Permeabilities are given as descriptive estimates based upon geological evidence. Values of porosity and specific yield are estimated mean values. It should be recognized that a range of values actually exists, particularly for the highly variable and stratified Merced formation.

Of the materials forming the aquifer, the Colma formation and dune sand possess relatively high permeabilities and specific yield, while the Merced formation has lower and more variable values as a result of its sand and clay layers. The Franciscan group has a low permeability so that it can be regarded for all practical purposes as forming an impermeable aquifer boundary.

Table A-1. Physical Properties of Geological
Materials Forming or Associated With the Daly
City Aquifer

<u>Rock Material</u>	<u>Permeability</u>	<u>Representative Porosity, Percent</u>	<u>Estimated Specific Yield, Percent</u>
Colma formation	Moderate to high; found above and below water table	34	20
Merced formation	Low to moderate	42	7
Dune sand	High; above water table in most places	33	24
Franciscan group	Low, except where fractured	17	2
Slope debris and ravine fill	Variable, but generally moderate to low	31	10
Recent alluvium	Moderate; high in clean sand	35	15
Artificial fill	High, except where clayey materials predominate	37	15

SECTION B
WELL INVENTORY

OBJECTIVES

In general, the well inventory program consisted of a data collecting and tabulating process to provide specific information regarding the characteristics of each well and its location. Certain basic objectives were formulated at the start which were designed to assure adequate coverage of this phase of the investigation. The principal objectives of the well inventory program herein reported are as follows:

1. To provide specific information with respect to the geological character of the aquifer by furnishing an adequate representation of well logs throughout the study area.
2. To obtain pertinent hydrological data of current ground water conditions in the aquifer, including historical information that would be useful in establishing depths to the ground water table, pumping requirements, and drawdown; and to relate this information sequentially in time.
3. To collect water quality data on past and present ground water extractions.
4. To establish by survey a vertical control net setting the elevation of reported well heads to

assure consistency of all reference points on the same vertical datum. This is especially important since any error of the water level caused by inconsistent elevation datum could result in misleading ground water slopes.

5. To review well data collected and tabulate the pertinent information for further study and presentation in exhibit form.
6. To prepare a location map showing pertinent wells within the study area and to identify by reference number those wells included in a summary of well data.

RESEARCH

Research began with a review and analysis of existing Daly City Water Division reports, maps, and records. A considerable amount of information was provided by the City Public Works Department which included the following:

Monthly Water Demand	1960-1970
Yearly Water Demand	1936-1937 and 1943-1969
Production Graphs	
Well History Graph	
Well Drawdown Test	1960
Yearly Production by Source	1968 and 1969
Well Logs for Wells 1, 2, 3, 10, 11 & 12	

Well Field Profile

Results of Water Analysis 1968, 1969, 1970

Results of PG&E Pump Tests 1970

Miscellaneous Hydrological Charts and Well Tables

DATA COLLECTION

The initial phase of data collection involved assembly of a list of known locations of existing wells in the aquifer extending from the Sunset District in San Francisco, southward to the City of San Bruno. Well locations were plotted on a composite map selected for this purpose.

This working list, consisting of approximately 45 wells, was given to Kirker, Chapman & Associates survey personnel who established by field survey the exact location and elevation of the top of each well listed. Again, this was to avoid using existing well elevations possibly based on different data which could result in poor correlations of well logs and water levels. For convenience and further use as a field work sheet, the information relating to elevation and location was plotted on aerial photo maps. Data obtained from these preliminary efforts was essential to implementing the subsequent work, involving interviews and data collection.

Contact was made with private water agencies and municipalities, other than Daly City, known to have operating wells in the basin. These included the California Water Service Company,

which operates wells in South San Francisco, and the City of San Bruno, located at the lower end of the aquifer. The existing well records of these agencies were exceptionally good; however, some well logs, water levels, and pumping information on abandoned wells were not complete. The assistance of these agencies in the further acquisition of reliable and pertinent data was excellent.

Of all agencies interviewed, the California Water Service Company had the most complete historical record of their well operations. This organization furnished well data containing the following information:

1. Well production data for the years from 1950 through 1970 from their South San Francisco Station and other wells in the San Bruno and San Mateo areas.
2. Graphs showing yearly static water changes at all of the above locations.
3. Station graphs from wells at Station No. 1 in South San Francisco showing pumping levels for each well from 1950 to December 1970.
4. Logs of five of their ten wells at Station No. 1.
5. A detailed map of their Station No. 1 Pumping Plant showing the location of all wells in that complex.

The City of San Bruno provided historical and current hydro-

logical data on their well system which included:

1. All available well and test hole logs in their files.
2. Pumping data for the years 1968 and 1969.
3. A table of water level changes at eight well locations from records extended over the period September 1942 to January 1955.
4. Current (1970) water quality information from tests made at their No. 12 well located at the end of Elm Avenue.
5. A print of the San Bruno City map showing the locations of currently operating wells and also the location of some abandoned wells for which logs were obtained.

A systematic gathering of relevant well information from private well users was included in the data collection process. Interviews were arranged with personnel of golf courses, cemeteries, and other private agencies known to be using well water from this aquifer for purposes of irrigation. Here again the spirit of cooperation of those contacted was excellent.

Six of these golf courses were operating irrigation systems whose water supplies came from wells in the aquifer: Harding Park Golf Course, San Francisco Golf Club, Olympic Golf Club, Lake Merced Golf and Country Club, California Golf Club of San Francisco, and Cypress Hills Golf Course. With the exception

of the Cypress Hills course, each of the above courses operate and maintain their own well systems. The Cypress Hills course receives its water for irrigation from wells operated by Olivet Cemetery. The investigation of abandoned wells at the Cypress Hills property was not pursued due to the difficulty of locating old records.

Harding Park Golf Course, located at the northern end of the aquifer, is one of the municipal courses operated by the City of San Francisco Recreation and Park Department. This course operates one well for light irrigation purposes and also pumps water from Lake Merced. Hydrological data on the wells was provided by the City of San Francisco Recreation and Park Department.

Fifteen cemeteries in and around Colma were studied in this well survey. Due to the long history of well operations in this area, and because of the expected nature and type of available well records maintained by these agencies for their own purposes, considerable and necessary time was expended in gathering and tabulating information for this report. It was found that some cemeteries were not pumping from wells but instead were procuring water for irrigation from the San Francisco Water Department. In the final analysis, it developed that 11 of the 15 cemeteries furnished usable data on 16 separate wells thus providing a good distribution of representative wells over this portion of the aquifer.

Some problems were encountered in acquiring specific data relative to depth to static water, current yield, and drawdown characteristics of existing wells. This type of information is not usually maintained by most irrigation system operators. In many instances, the most complete data was available on the original log prepared at the time of completion of wells. Depths to static water in many cemetery wells were furnished by pump repair service companies.

Well drilling companies known to have drilled water wells in the study area were contacted regarding well logs and other hydrological data in their records. These companies, including Roscoe Moss Co., Western Well Drilling Co., and J. N. Pitcher Co., were extremely helpful in providing the original well drillers' reports. Logs and other well information obtained from these sources made it possible to complete items missing from the records of some of the agencies previously contacted.

Pump supply and service companies were contacted regarding data from their records which would be useful for the purposes of this study. In some instances it was possible to acquire additional data regarding current depth to static water, pumping capacity, and drawdown characteristics on wells which had been serviced by these agencies. The Pump Repair Service Company in San Francisco was particularly helpful in this regard. This organization, in addition to supplying hydrological data from their records, rendered assistance in locating additional wells

in the area.

Eighty-six well locations were reviewed during the data collection activities associated with the well inventory. These wells do not constitute all of the well locations historically located in this basin. Obviously, there were abandoned farm wells whose locations and histories will never be found. However, in the combined accumulation of all of the data from those wells investigated, an abundance of information was obtained for the purposes of the ground water investigation. Fifty logs showing geological formation were obtained. Thirty-seven of these logs were for active wells now pumping from the aquifer; the remaining logs came from abandoned wells. Fifty-one active wells are included in the summary. Well depths vary from 204 feet to 645 feet. In addition to the well logs, six logs of soil test borings made in the sand dune area north and east of Lake Merced are included. These holes vary in depth between 30 and 60 feet.

WELL LOCATION MAP

All of the wells discussed in the preceding paragraphs are shown in Figure B-1, entitled "Well Location Map for the Daly City Aquifer and Vicinity." For convenience in cross-referencing, each well is identified with a number which corresponds with the item number of the well listed in the summary of well data found in Table B-1. Symbols designate active and abandoned wells and also those with and without geological logs.



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WELL LOCATION MAP

For The Daly City Aquifer And Vicinity



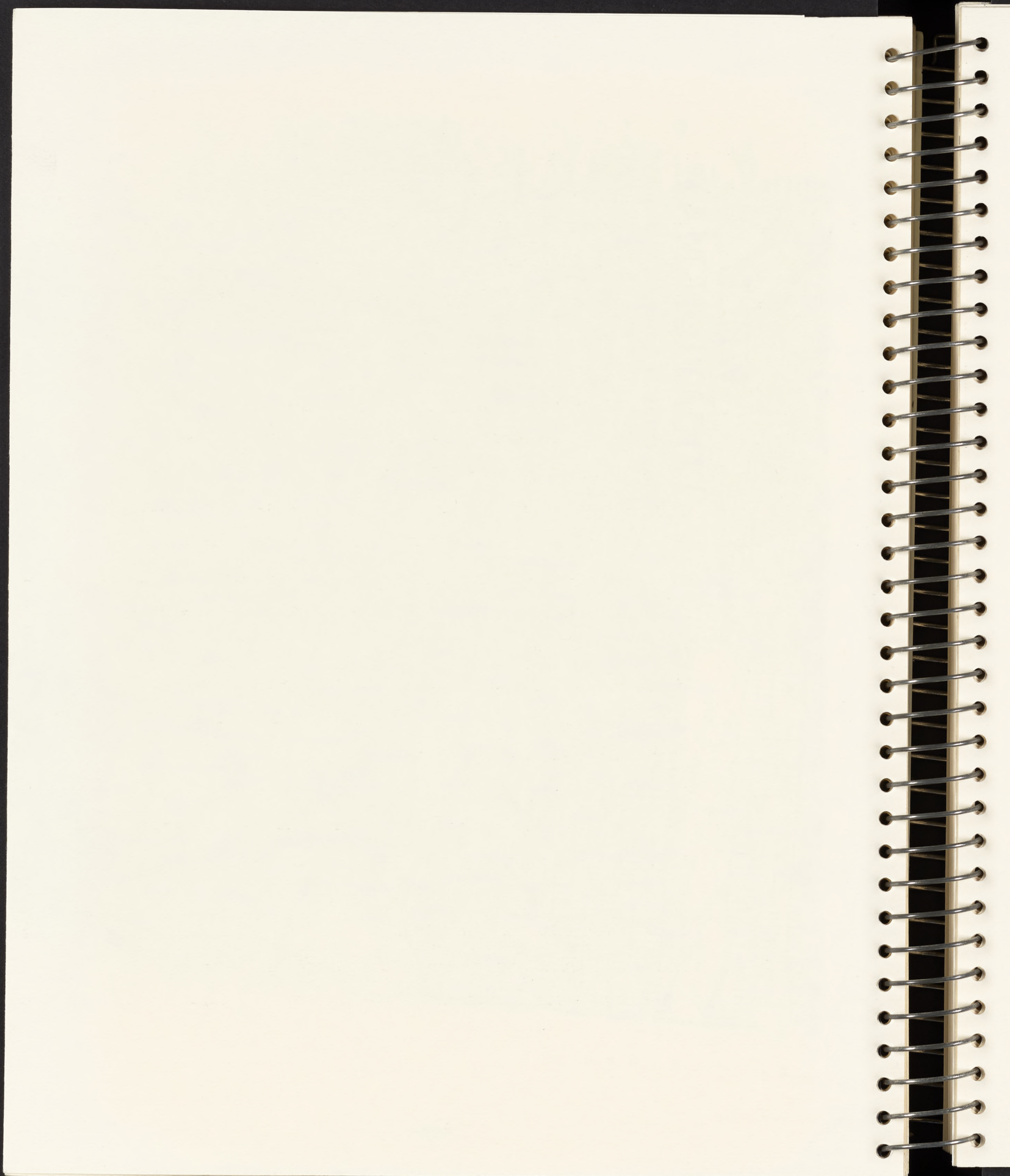
Figure B-1



STATISTICAL DATA ON WELLS

Pertinent statistical data on all wells and test holes considered in this study appears in Table B-1. Detailed basic data is assembled in the supporting data supplied the City Engineer. Following is a description of data presented by columns in Table B-1.

<u>Column Number</u>	<u>Description of Column Headings for Table B-1</u>
1	Item number designating a particular well. This number corresponds to the well location shown on Figure B-1.
2	Name of well owner. Soil test borings have no owner.
3	Map coordinates of well location. Coordinates are 1,000-meter Universal Transverse Mercator Grid, U. S. Geological Survey Map. Coordinates shown are in thousands of meters.
4	Well number designation supplied by owner. When no number was assigned by the owner, column is blank.
5	Date when well was drilled.
6	Name of well driller.
7	Indicates whether or not geological log was obtained.
8	Indicates whether or not water quality data was available.
9	Diameter of well casing in inches.
10	Method of drilling and well construction. Abbreviations used: R.T. - Hydraulic Rotary, C.T. - Cable Tool,



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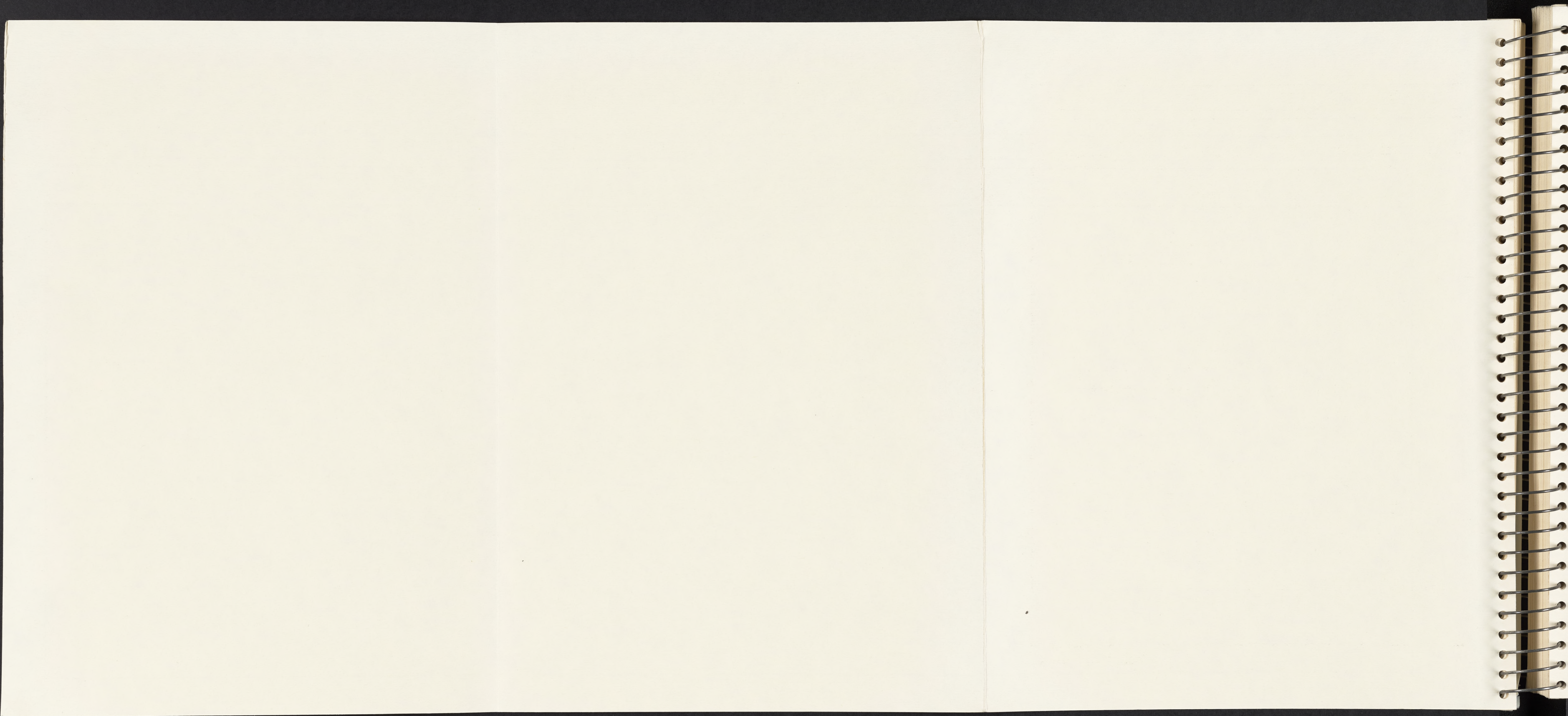
- D.G. - Dug Well, G.P. - well was gravel packed.
- 11 Yield of well in gallons per minute at time of most recent test of record. Figures with an asterisk (*) show maximum flow at the time when well was completed.
- 12 Drawdown is the difference between the pumping level and the recovery level measured at a definite time interval. Static level and recovery level are the same in most instances.
- 13 Specific capacity is obtained by dividing the yield of the well by the drawdown and is expressed as gallons per minute per foot.
- 14 Well depth below ground surface as shown on driller's log or as taken from information in owner's record.
- 15 Elevation of top of pump base established by Kirker, Chapman & Associates survey, conducted December 1970-January 1971. Data from U.S.C.&G.S. bench marks.
- 16 Elevation of bottom of well referenced to Column 15.
- 17 Distance from ground surface to static water in feet.
- 18 Elevation, referenced to Column 15, of static water obtained from soundings by driller at time of well completion or from records of owner; this does not necessarily represent current static water level.
- 19 Remarks

4	15	16	17	18	19
h	Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
	157.6	105.6	None	None	Certain Logs Taken From Circular No. 11, Institute of Transportation & Traffic Engineering. These are Test Holes Drilled By Various Agencies For Grading and Foundation Investigation Purposes and Are Tabulated Here As Part of The Log Data Collected For Determining Geological Stratification.
	200.1	145.1	None	None	
	434.6	374.6	None	None	
	118.6	78.6	None	None	
	99.6	69.6	None	None	
	189.8	144.8	None	None	
					North Windmill Well-No Detailed Data Available
					South Windmill Well-No Detailed Data Available
	67.25	-205.75	48	19	Active Well-Static Water at Approx. Lake Lev. Varies with Level Change in Lake.
	20.92	-183.08	21	0	Active Well
	132.16	-267.84	140	-8	Active Well 75 H.P. 300' Air Line Static Reading 1963
	48.22				Active Well-Yield in 1969
	62.31				Active Well-Yield in 1969
	66.67	-303.3	80	-13	Active Well-Yield in 1969-Air Line 160'
	69.63	-300.4			Active Well-Yield in 1969-Air Line 160'
					Aband. (D.C. Cnty. Line Well) Broke Suction When Pumped-Drawdown Not Known
	111.58	-276.4	231	-119	Active Pumping Cap & Distance to Static Water 1970
	112.67	-269.4	238	-125	Active Pumping Cap & Distance to Static Water 1970
	109.67	-304.3	188	-78	Active Pumping Cap & Distance to Static Water 1970
	217.5	-304.5	312	-94	Active Pumping Cap & Distance to Static Water 1970
	234.34		361	-127	Active Pumping Cap & Distance to Static Water 1970

- D.G. - Dug Well, G.P. - well was gravel packed.
- 11 Yield of well in gallons per minute at time of most recent test of record. Figures with an asterisk (*) show maximum flow at the time when well was completed.
- 12 Drawdown is the difference between the pumping level and the recovery level measured at a definite time interval. Static level and recovery level are the same in most instances.
- 13 Specific capacity is obtained by dividing the yield of the well by the drawdown and is expressed as gallons per minute per foot.
- 14 Well depth below ground surface as shown on driller's log or as taken from information in owner's record.
- 15 Elevation of top of pump base established by Kirker, Chapman & Associates survey, conducted December 1970-January 1971. Data from U.S.C.&G.S. bench marks.
- 16 Elevation of bottom of well referenced to Column 15.
- 17 Distance from ground surface to static water in feet.
- 18 Elevation, referenced to Column 15, of static water obtained from soundings by driller at time of well completion or from records of owner; this does not necessarily represent current static water level.
- 19 Remarks

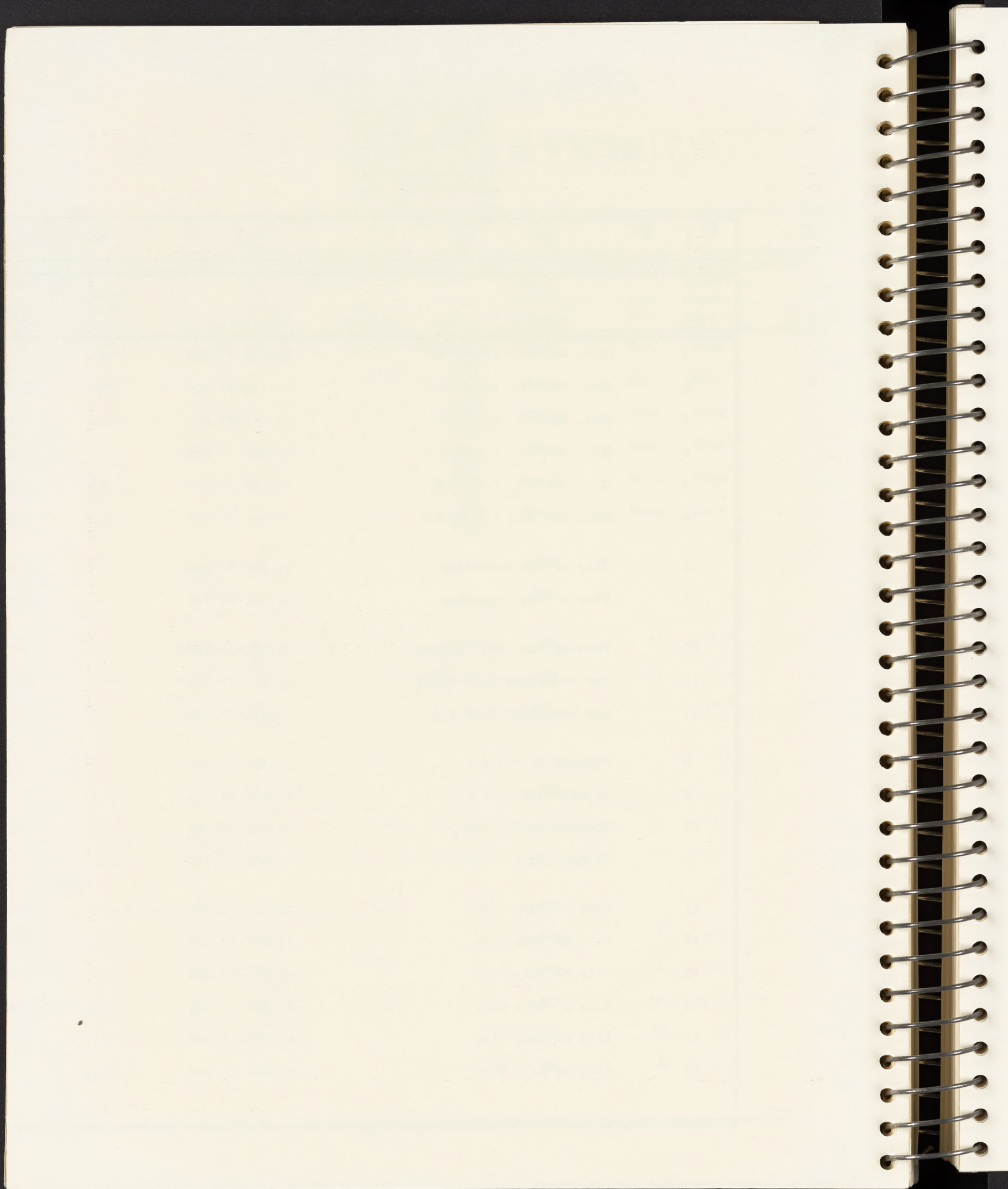
SUMMARY OF WELL DATA FOR THE DALY CITY AQUIFER & VICINITY 1970-1971

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Item	Owner	Location	Owner Designation	Date Drilled	Driller	Log	Water Quality Data	Casing Diameter	Type Well	Pump Discharge (g.p.m.)	Draw Down	Specific Capacity (g.p.m.)	Well Depth	Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
1	(Cir. No. 11, I.T.&T.E.)	45.03E-81.52N	410		No	Yes	No	None	Soil Test	None	None	None	52	157.6	105.6	None	None	Certain Logs Taken From Circular No. 11, Institute of Transportation & Traffic Engineering. These are Test Holes Drilled By Various Agencies For Grading and Foundation Investigation Purposes and Are Tabulated Here As Part of The Log Data Collected For Determining Geological Stratification.
4	(Cir. No. 11, I.T.&T.E.)	44.73E-77.96N	393	1950	No	Yes	No	None	Soil Test	None	None	None	55	200.1	145.1	None	None	
5	(Cir. No. 11, I.T.&T.E.)	45.95E-77.85N	367	1950	No	Yes	No	None	Soil Test	None	None	None	60	434.6	374.6	None	None	
6	(Cir. No. 11, I.T.&T.E.)	45.58E-74.73N	269	1948	No	Yes	No	None	Soil Test	None	None	None	40	118.6	78.6	None	None	
7	(Cir. No. 11, I.T.&T.E.)	45.58E-74.72N	269	1950	No	Yes	No	None	Soil Test	None	None	None	30	99.6	69.6	None	None	
14	(Cir. No. 11, I.T.&T.E.)	46.49E-74.18N	392	1949	No	Yes	No	None	Soil Test	None	None	None	45	189.8	144.8	None	None	
2	City of San Francisco	43.26E-80.26N		Unknown		No	No			1250								North Windmill Well-No Detailed Data Available
3	City of San Francisco	43.31E-79.67N		Unknown		No	No			800								South Windmill Well-No Detailed Data Available
85	Harding Park Golf Course	45.03E-74.97N		1931	Brunn	Yes	No	12	CT-GP	200	12	16.7	273	67.25	-205.75	48	19	Active Well-Static Water at Approx. Lake Lev. Varies with Level Change in Lake.
12	San Francisco Golf & C.C.	45.64E-73.30N	1	1917		Yes	No	14	AUG.-GP	195	91	2.2	204	20.92	-183.08	21	0	Active Well
13	San Francisco Golf & C.C.	45.97E-73.58N	2	1960	Moss	Yes	No	14		400	27	14.8	400	132.16	-267.84	140	-8	Active Well 75 H.P. 300' Air Line Static Reading 1963
8	Olympic Golf & C.C.	45.13E-73.37N	4			No	No			145				48.22				Active Well-Yield in 1969
9	Olympic Golf & C.C.	45.18E-73.35N	3			No	No			280				62.31				Active Well-Yield in 1969
10	Olympic Golf & C.C.	45.24E-73.26N	2	1956	Pitcher	Yes	No	14	CI-GP	245	50	4.9	370	66.67	-303.3	80	-13	Active Well-Yield in 1969-Air Line 160'
11	Olympic Golf & C.C.	45.35E-73.21N	1		Pitcher	Yes	No	14	CI-GP	290			370	69.63	-300.4			Active Well-Yield in 1969-Air Line 160'
15	City of Daly City	48.21E-73.34N	C/L No. 2	1918		No	No	12	CT	40			200					Aband. (D.C. Cnty. Line Well) Broke Suction When Pumped-Drawdown Not Known
18	City of Daly City	45.55E-72.01N	2	1955	Pitcher	Yes	Yes	14		347	5	69.5	388	111.58	-276.4	231	-119	Active Pumping Cap & Distance to Static Water 1970
19	City of Daly City	45.61E-72.00N	1	1954	Pitcher	Yes	Yes	14		405	4	101.3	382	112.67	-269.4	238	-125	Active Pumping Cap & Distance to Static Water 1970
20	City of Daly City	45.82E-71.94N	3	1962	Moss	Yes	Yes	14		549	48	11.4	414	109.67	-304.3	188	-78	Active Pumping Cap & Distance to Static Water 1970
23	City of Daly City	46.79E-72.37N	10	1950	Pitcher	Yes	Yes	14		485	83	5.8	522	217.5	-304.5	312	-94	Active Pumping Cap & Distance to Static Water 1970
24	City of Daly City	46.88E-72.21N	9		Pitcher	No	Yes			182	6	30.3		234.34		361	-127	Active Pumping Cap & Distance to Static Water 1970



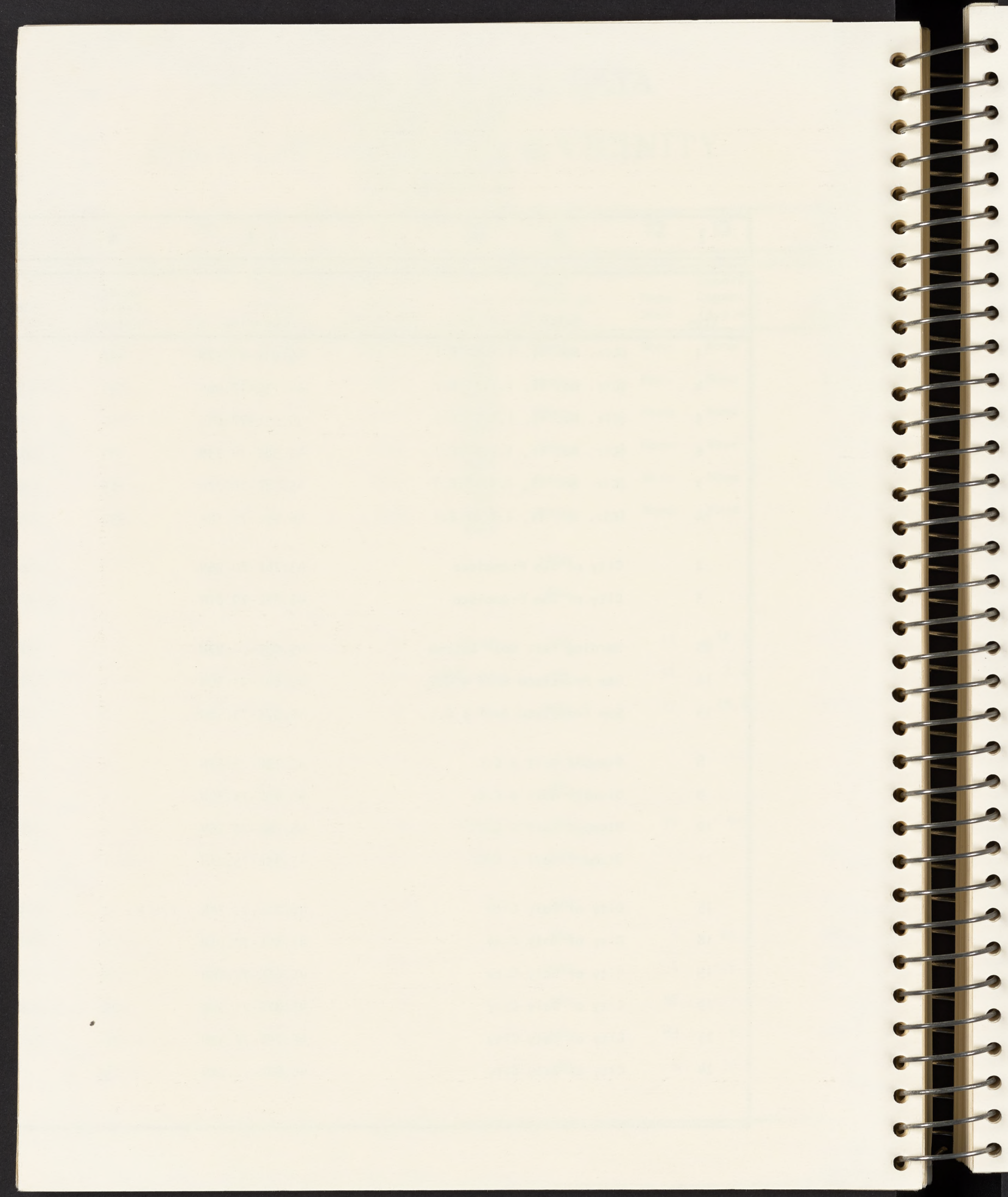
15	16	17	18	19
Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
231.95	-274.0	343	-111	Active Pumping Cap & Distance to Static Water 1970
231.71		368	-136	Active Pumping Cap & Distance to Static Water 1970
180.0	-372.0	251	-71	Active Pumping Cap & Distance to Static Water 1970
50	-200.0			Abandoned (Old Dug Well-Flowing) No Data Available Abandoned Irrig. Well Near Beach Used for Truck Crop Operation
155.52	-244.5	209	-53	Active
157.73	-292.3	207	-49	Active
		225		Irrigation Well-Abandoned
		45		Irrigation Well-Abandoned
		350		Aband. Well-No Data Avail.-Used by Colma Elem. Sch. til '60-Orig. Well for Irrig. Aband. '69-Pumped Water to Pig Ranch Above Cypress Lawn Golf Course
		180		From Pump Repair Service-Active Well Aband. Well-No Data Available
132.45	-472.5			Well Caved In-Working to Restore 12/21/70 Active Well
157.57	-242.4	223	-65	Dist. to Static, April 1970, Air Line at 350' Active Well
142.87	-187.1			No Data-Not in Use-Well was Dry When Olivet Pumped Their No. 3 Well
158.83	-242.2	225	-66	Active Well
		290		Back of Olivet Sign at El Camino Entrance-Abandoned
139.87	-420.1	209	-69	Active Well
258.85	-361.1	400	-141	Active Well-Temp. 60° Pitcher Logs are Lost-Cemetery Cannot Find Logs.

Table B-1, Continued



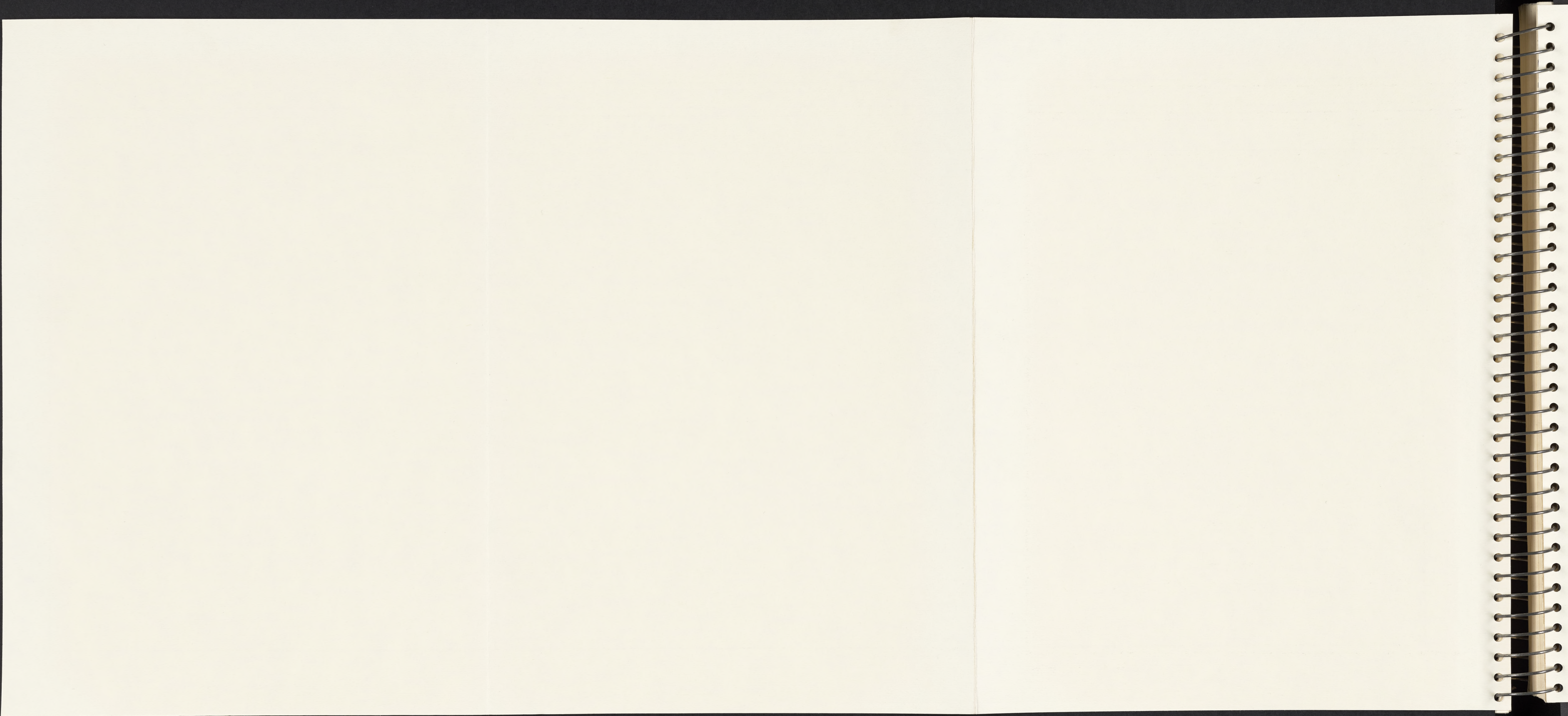
15	16	17	18	19
Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
231.95	-274.0	343	-111	Active Pumping Cap & Distance to Static Water 1970
231.71		368	-136	Active Pumping Cap & Distance to Static Water 1970
180.0	-372.0	251	-71	Active Pumping Cap & Distance to Static Water 1970
50	-200.0			Abandoned (Old Dug Well-Flowing) No Data Available Abandoned Irrig. Well Near Beach Used for Truck Crop Operation
155.52	-244.5	209	-53	Active
157.73	-292.3	207	-49	Active
		225		Irrigation Well-Abandoned
		45		Irrigation Well-Abandoned
		350		Aband. Well-No Data Avail.-Used by Colma Elem. Sch. til '60-Orig. Well for Irrig. Aband. '69-Pumped Water to Pig Ranch Above Cypress Lawn Golf Course
		180		From Pump Repair Service-Active Well Aband. Well-No Data Available
132.45	-472.5			Well Caved In-Working to Restore 12/21/70 Active Well
157.57	-242.4	223	-65	Dist. to Static, April 1970, Air Line at 350' Active Well
142.87	-187.1			No Data-Not in Use-Well was Dry When Olivet Pumped Their No. 3 Well
158.83	-242.2	225	-66	Active Well
		290		Back of Olivet Sign at El Camino Entrance-Abandoned
139.87	-420.1	209	-69	Active Well
258.85	-361.1	400	-141	Active Well-Temp. 60° Pitcher Logs are Lost-Cemetery Cannot Find Logs.

Table B-1, Continued



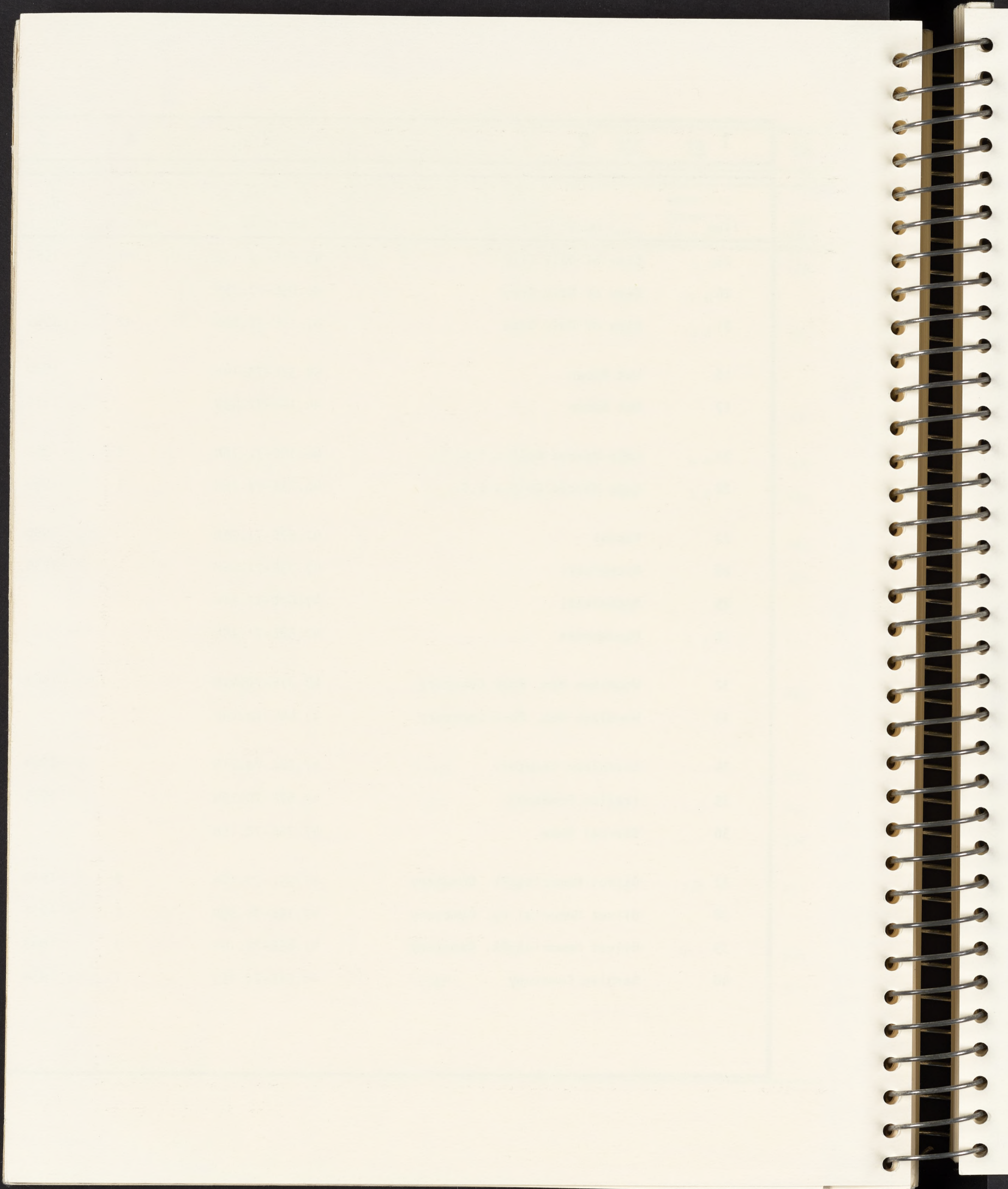
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Item	Owner	Location	Owner Designation	Date Drilled	Driller	Log	Water Quality Data	Casing Diameter	Type Well	Pump Discharge (g.p.m.)	Draw Down	Specific Capacity (g.p.m.)	Well Depth	Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
25	City of Daly City	46.91E-72.12N	11	1953	Pitcher	Yes	Yes	14		377	39	9.7	506	231.95	-274.0	343	-111	Active Pumping Cap & Distance to Static Water 1970
26	City of Daly City	46.85E-72.15N	8		Pitcher	No	Yes			296	27	11.0		231.71		368	-136	Active Pumping Cap & Distance to Static Water 1970
31	City of Daly City	47.14E-70.89N	12	1959	Western	Yes	Yes	14	GP	599	59	10.2	552	180.0	-372.0	251	-71	Active Pumping Cap & Distance to Static Water 1970
16	Not Known	52.32E-73.14N		1930		No	No											Abandoned (Old Dug Well-Flowing) No Data Available
17	Not Known	44.18E-72.43N		1935	Pitcher	No	No	12	CT	150			250	50	-200.0			Abandoned Irrig. Well Near Beach Used for Truck Crop Operation
21	Lake Merced Golf & C.C.	46.18E-72.18N	2	1964	Moss	Yes	No	14	RT-GP	300	68	4.4	400	155.52	-244.5	209	-53	Active
22	Lake Merced Golf & C.C.	46.23E-72.26N	1	1964	Moss	Yes	No	14	RT-GP	250	84	3.0	450	157.73	-292.3	207	-49	Active
27	Pacini	47.67E-71.72N		1950	Pitcher	Yes	No	10	CT				445			225		Irrigation Well-Abandoned
28	Micheletti	47.73E-71.46N		1950	Pitcher	Yes	No	8	CT				395			45		Irrigation Well-Abandoned
29	Micheletti	47.67E-71.31N				No	No				100							Aband. Well-No Data Avail.-Used by Colma Elem. Sch. til '60-Orig. Well for Irrig.
30	Piedamonte	47.68E-71.25N				No	No	8		110	40	2.7	450			350		Aband. '69-Pumped Water to Pig Ranch Above Cypress Lawn Golf Course
32	Woodlawn Mem. Park Cemetery	47.37E-70.47N		1962	Western	No	No	12	RT-GP	400			600			180		From Pump Repair Service-Active Well
33	Woodlawn Mem. Park Cemetery	47.44E-70.25N				No	No											Aband. Well-No Data Available
34	Greenlawn Cemetery	47.52E-70.21N		1964	Western	Yes	No	12	RT-GP				605	132.45	-472.5			Well Caved In-Working to Restore 12/21/70 Active Well
35	Italian Cemetery	47.67E-70.26N		1955	Pitcher	Yes	No		GP	250	100	2.5	400	157.57	-242.4	223	-65	Dist. to Static, April 1970, Air Line at 350' Active Well
36	Eternal Home	47.76E-70.15N											330	142.87	-187.1			No Data-Not in Use-Well was Dry When Olivet Pumped Their No. 3 Well
37	Olivet Memorial Pk. Cemetery	47.95E-70.17N	2	1953	Pitcher	Yes	No	14	CT-GP	100	35	2.9	401	158.83	-242.2	225	-66	Active Well
38	Olivet Memorial Pk. Cemetery	47.75E-70.09N	1	1951	Pitcher	No	No									290		Back of Olivet Sign at El Camino Entrance-Abandoned
39	Olivet Memorial Pk. Cemetery	47.85E-70.14N	3	1969	Moss	Yes	No	28	RT-GP	450	111	4.1	560	139.87	-420.1	209	-69	Active Well
40	Serbian Cemetery	48.52E-70.35N	1	1934	Pitcher	No	No	18	CT-GP	35			620	258.85	-361.1	400	-141	Active Well-Temp. 60° Pitcher Logs are Lost-Cemetery Cannot Find Logs.

Table B-1, Continued



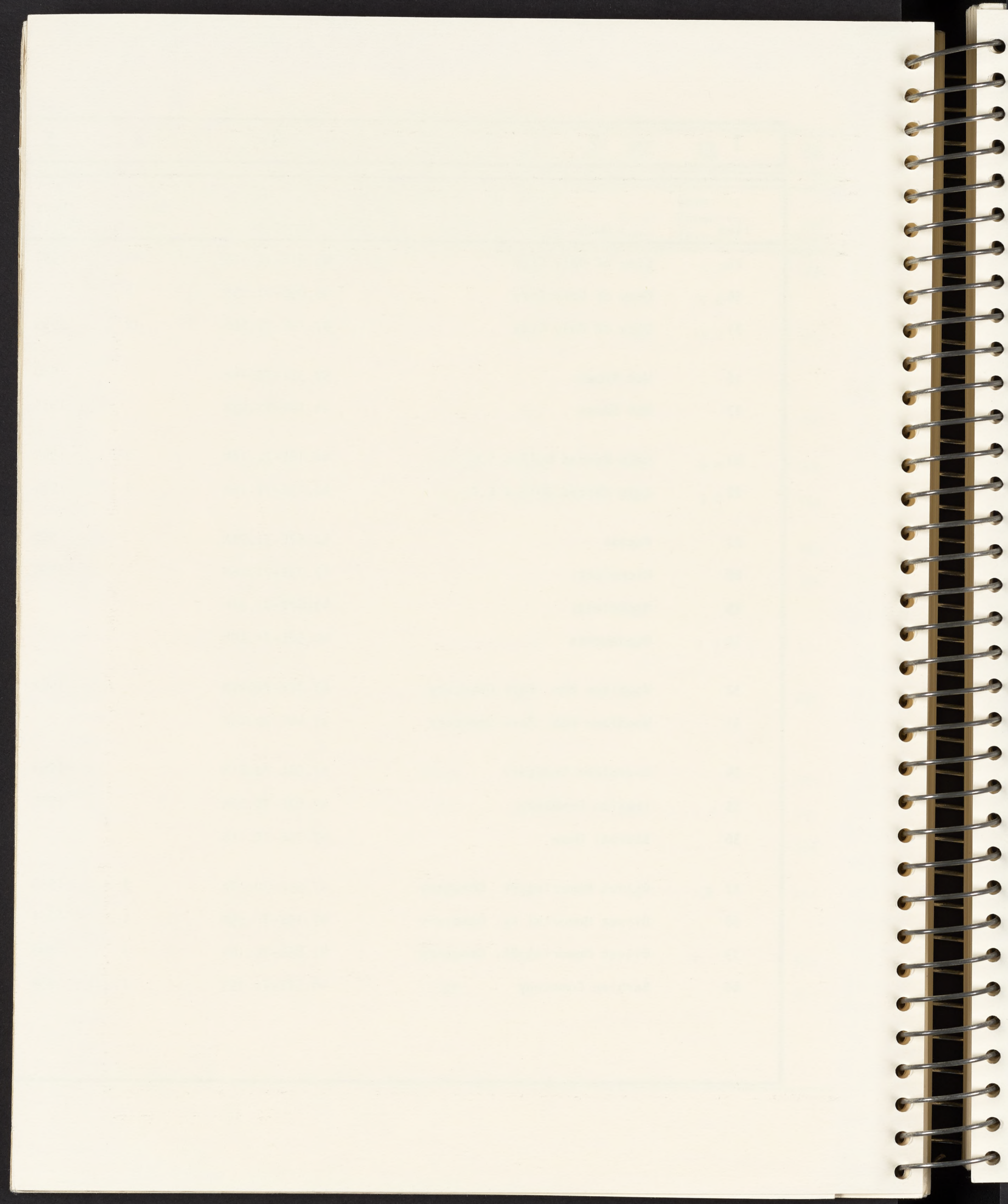
15	16	17	18	19
Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
254.03	-296.0	365	-111	Active Well-Temp.60°-Blue Clay Very Thick-Cemetery Cannot Find Logs.
114.55	-155.4			Active Well
118.67	-361.3	190	-71	Active Well- 350' Air Line
116.96	-428.0	178	-61	Active Well
105.6				Abandoned-No Data Available
151.09	-465.9	240	-89	Active Well
91.58				Abandoned-No Data Available
144.37	-459.6	195	-51	Active Well
121.4	-360.6			Active-No Air Line
126.5	-373.5	206	-79	Active
		325		Abandoned Well-School Irrig.
				Irrig. Well-No Data-Abandoned
				School Irrig.-Well Abandoned 1970 No Data Available
				Irrig.-Active Well-No Detailed Data Available Active Well-Used for Nursery Irrigation
38.56	-536.5	163	-124	Pump Test Made June '70-Active Well
37.16	-237.8	164	-127	Active Well
34.59	-345.4	160	-125	Active Well
32.82				Abandoned Well
33.52	-422.5	164	-130	Pump Test Made June '70-Active Well

Table B-1. Continued



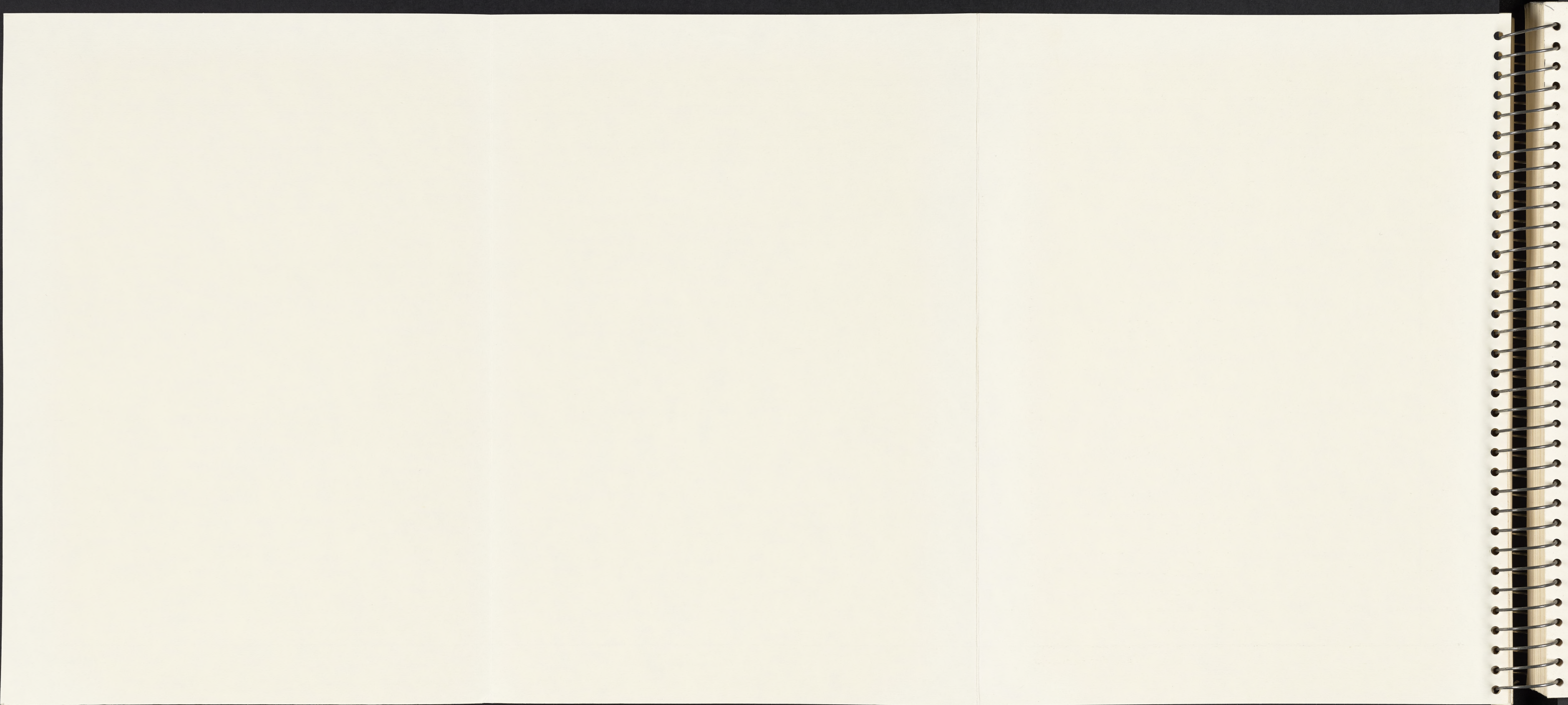
15	16	17	18	19
Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
254.03	-296.0	365	-111	Active Well-Temp.60°-Blue Clay Very Thick-Cemetery Cannot Find Logs.
114.55	-155.4			Active Well
118.67	-361.3	190	-71	Active Well- 350' Air Line
116.96	-428.0	178	-61	Active Well
105.6				Abandoned-No Data Available
151.09	-465.9	240	-89	Active Well
91.58				Abandoned-No Data Available
144.37	-459.6	195	-51	Active Well
121.4	-360.6			Active-No Air Line
126.5	-373.5	206	-79	Active
		325		Abandoned Well-School Irrig.
				Irrig. Well-No Data-Abandoned
				School Irrig.-Well Abandoned 1970 No Data Available
				Irrig.-Active Well-No Detailed Data Available
				Active Well-Used for Nursery Irrigation
38.56	-536.5	163	-124	Pump Test Made June '70-Active Well
37.16	-237.8	164	-127	Active Well
34.59	-345.4	160	-125	Active Well
32.82				Abandoned Well
33.52	-422.5	164	-130	Pump Test Made June '70-Active Well

Table B-1. Continued



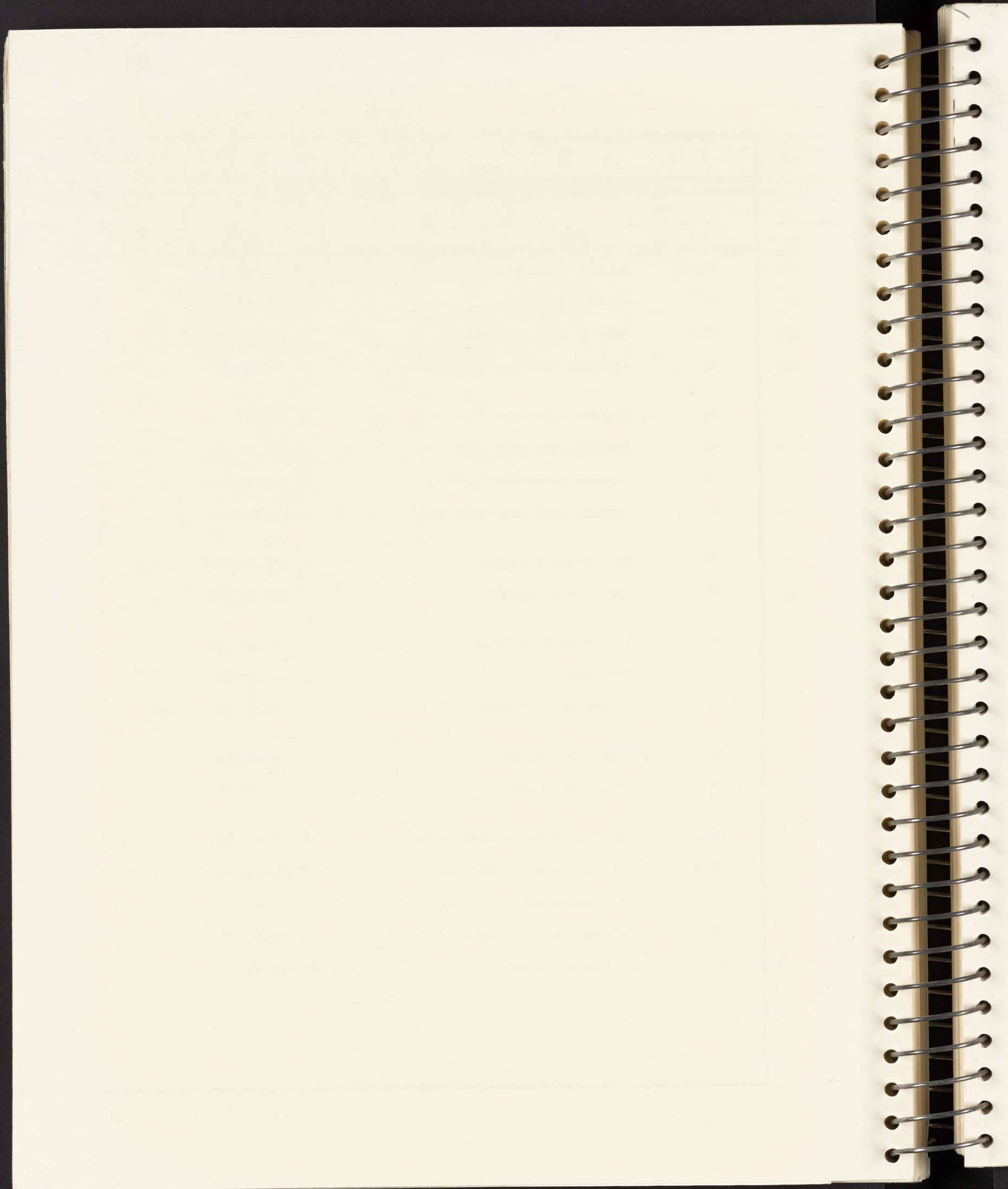
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Item	Owner	Location	Owner Designation	Date Drilled	Driller	Log	Water Quality Data	Casing Diameter	Type Well	Pump Discharge (g.p.m.)	Draw Down	Specific Capacity (g.p.m.)	Well Depth	Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
86	Serbian Cemetery	48.47E-70.30N	2	1946	Pitcher	No	No	14	CT-GP	85	20	4.3	550	254.03	-296.0	365	-111	Active Well-Temp.60°-Blue Clay Very Thick-Cemetery Cannot Find Logs.
41	Salem Cemetery	47.89E-69.91N		1933	Holgarth	No	No		Hand Auger	50			270	114.55	-155.4			Active Well
42	Home of Peace Cemetery	48.00E-69.85N	3	1966	Moss	Yes	No	12	RT-GP	250	32	7.8	480	118.67	-361.3	190	-71	Active Well- 350' Air Line
43	Hills of Eternity Cemetery	48.18E-69.73N	5	1965	Moss	Yes	No	12	RT-GP	200	30	6.7	545	116.96	-428.0	178	-61	Active Well
44	Cypress Lawn Mem. Park Cem.	48.23E-69.61N												105.6				Abandoned-No Data Available
45	Cypress Lawn Mem. Park Cem.	48.35E-69.75N	2	1964	Western	Yes	No	14	RT-GP	445*	58	7.7	617	151.09	-465.9	240	-89	Active Well
46	Cypress Lawn Mem. Park Cem.	48.35E-69.47N	2	1964	Western	Yes	No							91.58				Abandoned-No Data Available
47	Cypress Lawn Mem. Park Cem.	48.46E-69.44N	3	1962	Western	Yes	No	12	RT-GP	400	105	3.8	604	144.37	-459.6	195	-51	Active Well
48	Holy Cross Cemetery	48.52E-69.28N	2	1948	Pitcher	Yes	No	14		300			482	121.4	-360.6			Active-No Air Line
49	Holy Cross Cemetery	48.58E-69.22N	1	1960	Moss	Yes	No	14	RT-GP	460	68	6.8	500	126.5	-373.5	206	-79	Active
50	El Camino High School	49.73E-69.20N				No	No									325		Abandoned Well-School Irrig.
51	Unknown	45.11E-67.82N				No	No											Irrig. Well-No Data-Abandoned
52	El Camino High School	49.15E-68.76N				No	No											School Irrig.-Well Abandoned 1970 No Data Available
53	Micheletti Nursery	50.37E-68.81N				No	No			60			300					Irrig.-Active Well-No Detailed Data Available
54	Micheletti Nursery	50.33E-68.37N				No	No			50			300					Active Well-Used for Nursery Irrigation
55	California Water Service Co.	50.03E-67.76N	18			Yes	Yes	12		287	37	7.8	575	38.56	-536.5	163	-124	Pump Test Made June '70-Active Well
56	California Water Service Co.	50.09E-67.81N	4			No	Yes			60	16	3.8	275	37.16	-237.8	164	-127	Active Well
57	California Water Service Co.	50.20E-67.70N	17			Yes	Yes	16		51	18	2.8	380	34.59	-345.4	160	-125	Active Well
58	California Water Service Co.	50.26E-67.67N	9			No	No							32.82				Abandoned Well
61	California Water Service Co.	60.21E-67.55N	15	1925	Adams	Yes	Yes	12		185	41	4.5	456	33.52	-422.5	164	-130	Pump Test Made June '70-Active Well

Table B-1. Continued



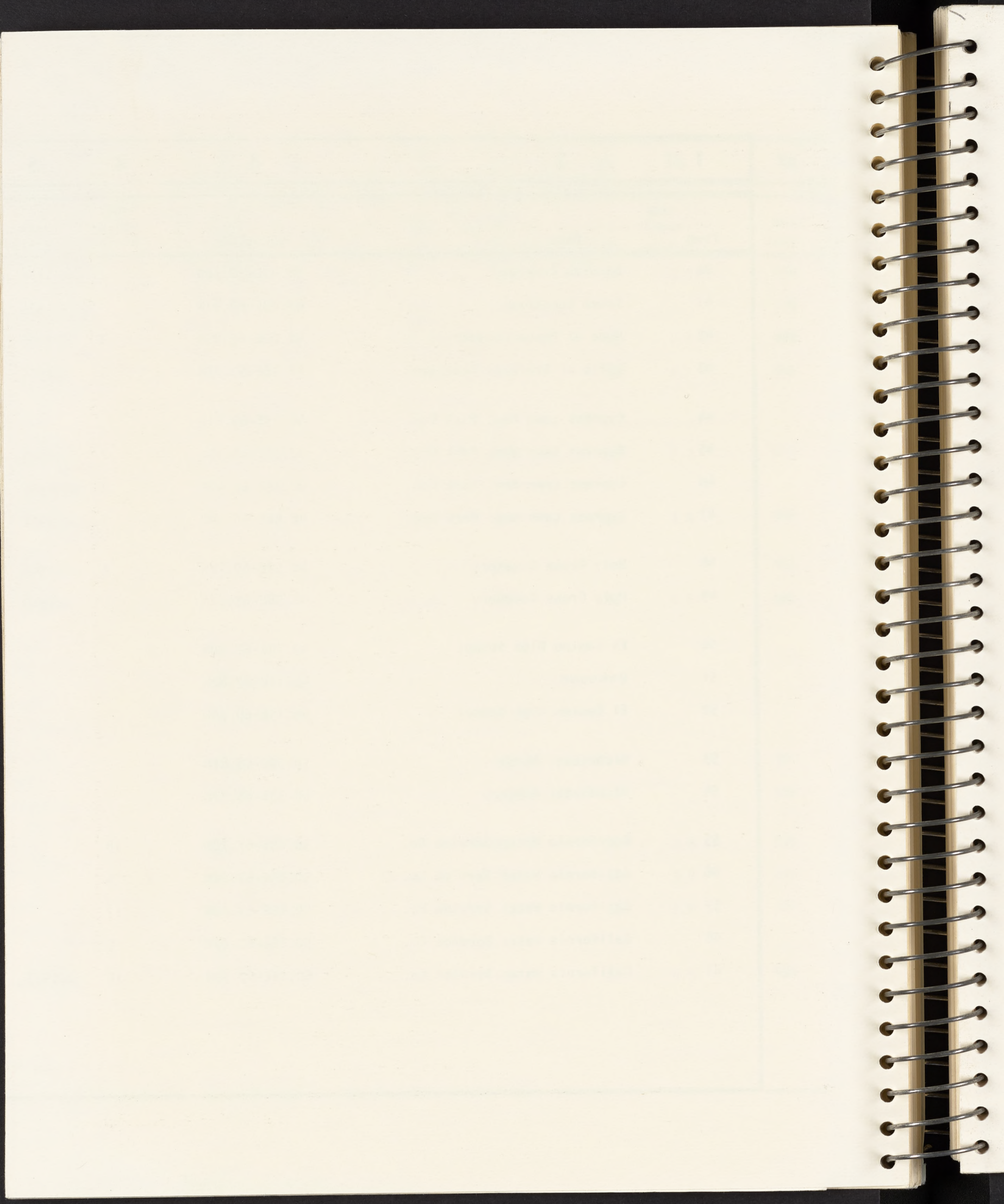
15	16	17	18	19
Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
30.57	-218.4	168	-137	Active Well
31.20				Abandoned Well
29.63	-437.4	148	-118	Pump Test Made June '70-Active Well
29.83				Abandoned Well
28.08	-499.9	164	-136	Pump Test Made June '70-Active Well
56.35	-546.6	150	-94	Active Well-NOTE: Golf Course Only Pumps One Well at a Time
54.50	-555.5	159	-104	Active Well
		325		Aband. Well-Pump Removed & Well Filled In
110.37	-491.6	153	-43	Exist. Well Not Active Since '66 Irrig. With Purchased Water Fr. S.F.W.D.
110.12				Exist. Well at Main. Yd. Not Active Since '66-Irrig. With Purchased Water From S.F.W.D.
63.15	-581.8			Exist. Well Not Active Since '66
85	-415	241		Active Well Nursery Irrig. Pumping From 338'
78.71	-391.3	258	-179	Elm Avenue Well-Active Well
		190		Cedar Avenue Well-Abandoned
		147		Maple Avenue Well, Mills Addit.-Aband.
90.9	-335.1	171	-80	Chestnut Avenue Well-Abandoned
77.2	-397.8	157	-80	Oak Avenue Well in Park-Abandoned
32.39	-442.6	194	-162	City Hall Parking Lot Well-Act. Well At City Yard
13.44				No Data-Abandoned Well
13.62	-166.4			Milton Avenue At City Yard-Active Well
11.48	-413.5	89	-78	City Yard Huntington-Active Well
11.54				City Yard Huntington-Abandoned Well
12.46	-187.5			San Felipe & Huntington-Active Well
		90		San Marco Avenue-Well Abandoned

Table B-1, Concluded



15	16	17	18	19
Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
30.57	-218.4	168	-137	Active Well
31.20				Abandoned Well
29.63	-437.4	148	-118	Pump Test Made June '70-Active Well
29.83				Abandoned Well
28.08	-499.9	164	-136	Pump Test Made June '70-Active Well
56.35	-546.6	150	-94	Active Well-NOTE: Golf Course Only
54.50	-555.5	159	-104	Pumps One Well at a Time
		325		Active Well
110.37	-491.6	153	-43	Aband. Well-Pump Removed & Well Filled In
110.12				Exist. Well Not Active Since '66
63.15	-581.8			Irrig. With Purchased Water Fr. S.F.W.D.
				Exist. Well at Main. Yd. Not Active Since '66-Irrig. With Purchased Water From S.F.W.D.
85	-415	241		Exist. Well Not Active Since '66
				Active Well Nursery Irrig. Pumping From 338'
78.71	-391.3	258	-179	Elm Avenue Well-Active Well
		190		Cedar Avenue Well-Abandoned
		147		Maple Avenue Well, Mills Addit.-Aband.
90.9	-335.1	171	-80	Chestnut Avenue Well-Abandoned
77.2	-397.8	157	-80	Oak Avenue Well in Park-Abandoned
32.39	-442.6	194	-162	City Hall Parking Lot Well-Act. Well At City Yard
13.44				No Data-Abandoned Well
13.62	-166.4			Milton Avenue At City Yard-Active Well
11.48	-413.5	89	-78	City Yard Huntington-Active Well
11.54				City Yard Huntington-Abandoned Well
12.46	-187.5			San Felipe & Huntington-Active Well
		90		San Marco Avenue-Well Abandoned

Table B-1, Concluded



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Item	Owner	Location	Owner Designation	Date Drilled	Driller	Log	Water Quality Data	Casing Diameter	Type Well	Pump Discharge (g.p.m.)	Draw Down	Specific Capacity (g.p.m.)	Well Depth	Top Elev.	Bottom Elev.	Dist. To Static Water	Static Water Elev.	Remarks
62	California Water Service Co.	50.30E-67.61N	2			No	No			75	15	5.0	249	30.57	-218.4	168	-137	Active Well
53	California Water Service Co.	50.35E-67.56N	16			No	No							31.20				Abandoned Well
64	California Water Service Co.	50.39E-67.60N	14	1943	Still	Yes	Yes	12		112	21	5.3	467	29.63	-437.4	148	-118	Pump Test Made June '70-Active Well
65	California Water Service Co.	50.47E-67.62N	12			No	No							29.83				Abandoned Well
66	California Water Service Co.	50.55E-67.63N	19			Yes	No	16	RT-GP	175	36	4.9	528	28.08	-499.9	164	-136	Pump Test Made June '70-Active Well
59	California Golf Club - S.F.	49.73E-67.40N	4	1960	Moss	Yes	Yes	14	RT-GP	500	42	11.9	603	56.35	-546.6	150	-94	Active Well-NOTE: Golf Course Only Pumps One Well at a Time
60	California Golf Club - S.F.	49.82E-67.38N	5	1966	Moss	Yes	Yes	14	RT-GP	520	38	13.7	610	54.50	-555.5	159	-104	Active Well
67	Golden Gate National Cemetery	49.88E-65.34N	3	1952	Western	Yes	No	14	GP	500*	65	7.7	630			325		Aband. Well-Pump Removed & Well Filled In
68	Golden Gate National Cemetery	50.40E-65.38N	2	1941	Western	Yes	No	14	GP	300*	128	2.3	602	110.37	-491.6	153	-43	Exist. Well Not Active Since '66 Irrig. With Purchased Water Fr. S.F.W.D.
70	Golden Gate National Cemetery	50.67E-65.25N	4			No	No							110.12				Exist. Well at Main. Yd. Not Active Since '66-Irrig. With Purchased Water
71	Golden Gate National Cemetery	51.12E-65.49N	5	1960	Western	Yes	No	14	GP				645	63.15	-581.8			From S.F.W.D. Exist. Well Not Active Since '66
69	Avansino-Mortensen Co.	50.91E-63.33N		1942		No	No	12	GP	35			500	85	-415	241		Active Well Nursery Irrig. Pumping From 338'
72	City of San Bruno	51.37E-64.56N	12	1959	Western	Yes	Yes	14	GP	670	34	19.7	470	78.71	-391.3	258	-179	Elm Avenue Well-Active Well
73	City of San Bruno	50.94E-63.79N	2-A	1948	Moss	Yes	No	14	GP	670	46	14.6	426			190		Cedar Avenue Well-Abandoned
74	City of San Bruno	51.06E-63.73N	2	1942	Moss	Yes	No	14	GP	760	53	14.3	426			147		Maple Avenue Well, Mills Addit.-Aband.
75	City of San Bruno	51.18E-63.85N	2-B	1948	Moss	Yes	No	14	CT-GP	600*	45	13.3	426	90.9	-335.1	171	-80	Chestnut Avenue Well-Abandoned
76	City of San Bruno	51.30E-63.88N		1948	Moss	Yes	No	14	CT-GP	725*	68	10.7	475	77.2	-397.8	157	-80	Oak Avenue Well in Park-Abandoned
77	City of San Bruno	51.82E-64.04N	13	1966	Moss	Yes	Yes	14	GP	405*	61	6.6	475	32.39	-442.6	194	-162	City Hall Parking Lot Well-Act. Well At City Yard
78	City of San Bruno	52.49E-63.73N				No	No							13.44				No Data-Abandoned Well
79	City of San Bruno	52.46E-63.67N	5			No	No						180	13.62	-166.4			Milton Avenue At City Yard-Active Well
80	City of San Bruno	52.52E-63.64N	3	1946	Moss	Yes	Yes	14	GP	620*	85	7.3	425	11.48	-413.5	89	-78	City Yard Huntington-Active Well
81	City of San Bruno	52.54E-63.60N				No	No							11.54				City Yard Huntington-Abandoned Well
82	City of San Bruno	52.58E-63.58N	1			No	No						200	12.46	-187.5			San Felipe & Huntington-Active Well
83	City of San Bruno	52.46E-63.29N	6	1942	Moss	Yes	No	14	GP	300*	50	6.0	479			90		San Marco Avenue-Well Abandoned

Table B-1, Concluded

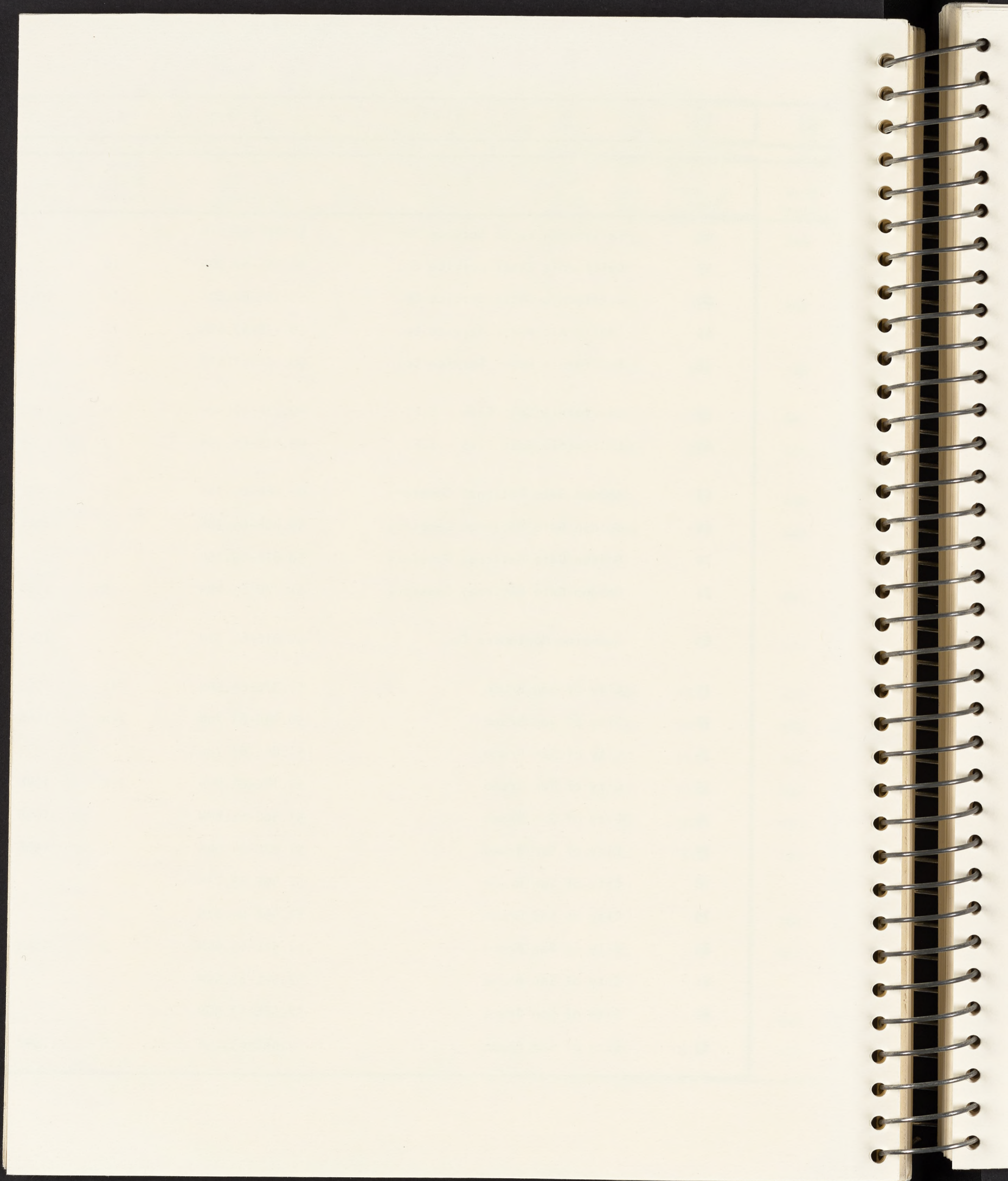


SECTION C
STORAGE VOLUME OF AQUIFER

SPECIFIC YIELD VALUES

In order to obtain the best possible estimate of the volume of ground water stored in the Daly City aquifer, the 49 well logs in the Summary of Well Data, Table B-1, were examined in detail. For each geological strata shown a specific yield defined as the ratio of the volume of water released when drained by gravity to the gross volume of the aquifer, was assigned using values recommended by the U. S. Geological Survey for interpreting drillers' terms (See Table C-1). The values, ranging from 0.03 for clay to 0.25 for sand, were then weighted according to the thickness of the strata to obtain a single weighted value for each well. In turn, the well values for each aquifer section (The sections of the aquifer are defined in terms of the areas between geological cross-sections shown in Figure A-1) were averaged to produce a mean specific yield value for each aquifer section. These results are summarized in Table C-2.

It can be seen from Table C-2 that the specific yields range from 0.06 to 0.18. There is a generally pronounced trend of decreasing values from north to south. From a geological standpoint this can be attributed to a predominance of sand and dune sand in the vicinity of Lake Merced, changing



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Table C-1. DRILLERS' TERMS USED IN ESTIMATING SPECIFIC YIELD *

Crystalline Bedrock (fresh) Specific yield zero		Clay and Gravel, Sandy Clay, and Similar Materials (continued)	
Granite	Hard rock	Ash	Hard pumice
Hard boulders	Graphite and rocks	Caliche	Porphyry
Hard granite	Rock (if in area of known crystalline rocks)	Chalk	Seepage soft clay
		Hard lava formation	Volcanic ash
Clay and Related Materials Specific yield 3 percent		Fine Sand, Tight Sand, Tight Gravel, and Similar Materials Specific yield 10 percent	
Adobe	Lava	Sand and clay	Sandy loam
Brittle clay	Loose shale	Sand and clay strata (traces)	Sandy loam, sand, and clay
Caving clay	Muck	Sand and dirt	Sandy silt
Cement	Mud	Sand and hardpan	Sandy soil
Cement ledge	Packed clay	Sand and hard sand	Surface and fine sand
Choppy clay	Poor clay	Sand and lava	
Clay	Shale	Sand and pack sand	Cloggy sand
Clay, occasional rock	Shell	Sand and sandy clay	Coarse pack sand
Crumbly clay	Slush	Sand and soapstone	Compacted sand and silt
Cube clay	Soapstone	Sand and soil	Dead sand
Decomposed granite	Soapstone float	Sand and some clay	Dirty sand
Dirt	Soft clay	Sand, clay, and water	Fine pack sand
Good clay	Squeeze clay	Sand crust	Fine quicksand with alkali streak
Gumbo clay	Sticky	Sand-little water	Fine sand
Hard clay	Sticky clay	Sand, mud, and water	Fine sand, loose
Hardpan (H.P.)	Tiger clay	Sand (some water)	Hard pack sand
Hardpan shale	Tight clay	Sand streaks, balance clay	Hard sand
Hard shale	Tule mud	Sand, streaks of clay	Hard sand and streaks of sandy clay
Hard shell	Variable clay	Sand with cemented streaks	
Joint clay	Volcanic rock	Sand with thin streaks of clay	Hard sand rock and some water sand
Clay and Gravel, Sandy Clay, and Similar Materials Specific yield 5 percent			Hard sand, soft streaks
Cemented gravel (cobbles)	Clay and sandy clay	Coarse, and sandy	Loamy fine sand
Cemented gravel and clay	Clay and silt	Loose sandy clay	Medium muddy sand
Cemented gravel, hard	Clay, cemented sand	Medium sandy	Milk sand
Cement and rocks (cobbles)	Clay, compact loam and sand	Sandy	More or less sand
Clay and gravel (rock)	Clay to coarse sand	Sandy and sandy clay	Muddy sand
Clay and boulders (cobbles)	Clay, streaks of hard packed sand	Sandy clay, sand, and clay	Pack sand
Clay, pack sand, and gravel	Clay, streaks of sandy clay	Sandy clay—water bearing	Poor water sand
Cobbles in clay	Clay, water	Sandy clay with streaks of sand	Powder sand
Conglomerate	Clay with sandy pocket	Sandy formation	Pumice sand
Dry gravel (below water table)	Clay with small streaks of sand	Sandy muck	Quicksand
Gravel and clay	Clay with some sand	Sandy sediment	Sand, mucky or dirty
Gravel (cement)	Clay with streaks of fine sand	Very sandy clay	Set sand
Gravel and sandy clay	Clay with thin streaks of sand		Silty sand
Gravel and tough shale	Porphyry clay	Boulders, cemented sand	Sloppy sand
Gravelly clay	Quicksandy clay	Cement, gravel, sand, and rocks	Sticky sand
Rocks in clay	Sand—clay	Clay and gravel, water bearing	Streaks fine and coarse sand
Rotten cement	Sand shell	Clay & rock, some loose rock	Surface sand and clay
Rotten concrete mixture	Shale and sand	Clay, sand and gravel	Tight sand
Sandstone and float rock	Solid clay with strata of cemented sand	Clay, silt, sand, and gravel	
Silt and gravel	Sticky sand and clay	Conglomerate, gravel, and boulders	Brittle clay and sand
Soil and boulders	Tight muddy sand	Conglomerate, sticky clay, sand and gravel	Clay and sand
	Very fine tight muddy sand	Dirty gravel	Clay, sand, and water
Cemented sand		Fine gravel, hard	Clay with sand
Cemented sand and clay	Dry sandy silt	Gravel and hardpan strata	Clay with sand streaks
Clay sand	Fine sandy loam	Gravel, cemented sand	More or less clay, hard sand and boulders
Dry hard packed sand	Fine sandy silt	Gravel with streaks of clay	Mud and sand
Dry sand (below water table)	Ground surface	Hard gravel	Mud, sand, and water
Dry sand and dirt	Loam	Hard sand and gravel	Sand and mud with chunks of clay
Fine muddy sand	Loam and clay	Packed gravel	Silt and fine sand
Fine sand, streaks of clay	Sandy clay loam	Packed sand and gravel	Silt and sand
Fine tight muddy sand	Sediment	Quicksand and cobbles	Soil, sand, and clay
Hard packed sand, streaks of clay	Silt	Rock sand and clay	Topsoil and light sand
Hard sand and clay	Silt and clay	Sand and gravel, cemented streaks	Water sand sprinkled with clay
Hard set sand and clay	Silty clay loam	Sand and silt, many gravel	Float rock (stone)
Muddy sand and clay	Silty loam	Sand, clay, streaks of gravel	Laminated
Packed sand and clay	Soft loam	Sandy clay and gravel	Pumice
Packed sand and shale	Soil	Set gravel	Seep water
Sand and clay mix	Soil and clay	Silty sand and gravel (cobbles)	Soft sandstone
Sand and tough shale	Soil and mud	Tight gravel	Strong seepage
Sand rock	Soil and sandy shale		
Sandstone	Surface formation		
Sandstone and lava	Top hardpan soil		
Set sand and clay	Topsoil		
Set sand, streaks of clay	Topsoil and sandy silt		
Cemented sandy clay	Topsoil—silt		
Hard sandy clay (tight)			
Sandy clay	Decomposed hardpan		
Sandy clay with small sand streaks, very fine	Hardpan and sandstone		
Sandy shale	Hardpan and sandy clay		
Set sandy clay	Hardpan and sandy shale		
Silty clay	Hardpan and sandy stratas		
Soft sandy clay	Hard rock (alluvial)		
Clay and fine sand	Sandy hardpan		
Clay and pumice streaks	Semi-hardpan		
	Washboard		
		Gravel, Sand, Sand and Gravel, and Similar Materials Specific yield 25 percent	
		Boulders	Gravel and sand
		Coarse gravel	Gravel and sandrock
		Coarse sand	Medium sand
		Cobbles	Rock and gravel
		Cobble stones	Running sand
		Dry gravel (if above water table)	Sand
		Float rocks	Sand, water
		Free sand	Sand and boulders
		Gravel	Sand and cobbles
		Loose gravel	Sand and fine gravel
		Loose sand	Sand and gravel
		Rocks	Sandy gravel
			Water gravel

*Todd D. K. (editor), The Water Encyclopedia, Water Information Center, Port Washington, New York, 1970, p. 205.

Table C-2. Specific Yield Values of the
Daly City Aquifer

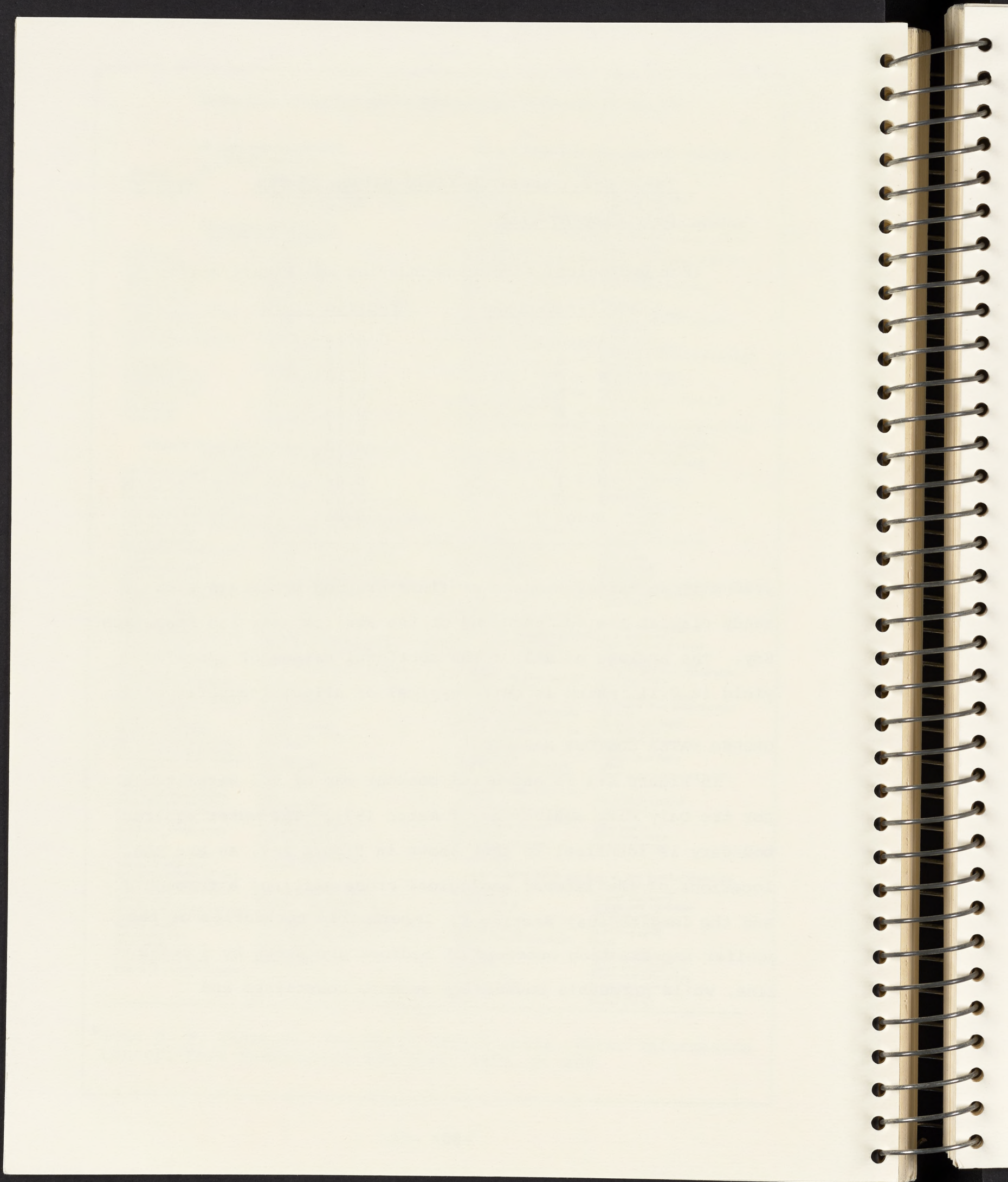
(For geological section boundaries see Figure A-1)

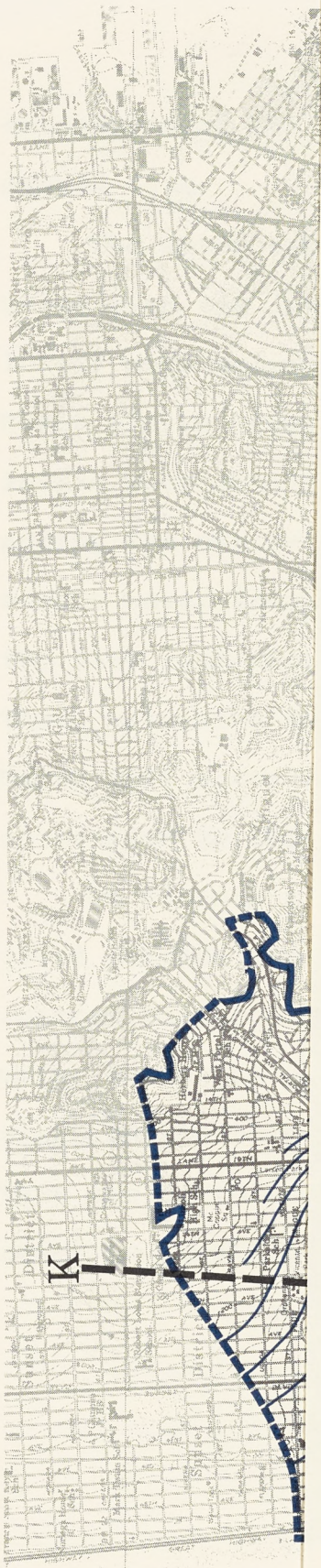
<u>Aquifer Section</u>	<u>Specific Yield</u>
Above A	0.18
A - B	0.15
B - C	0.10
C - D	0.14
D - E	0.13
E - F	0.11
F - G	0.10
G - H	0.12
H - I	0.06
I - J	0.08
Below J	0.08

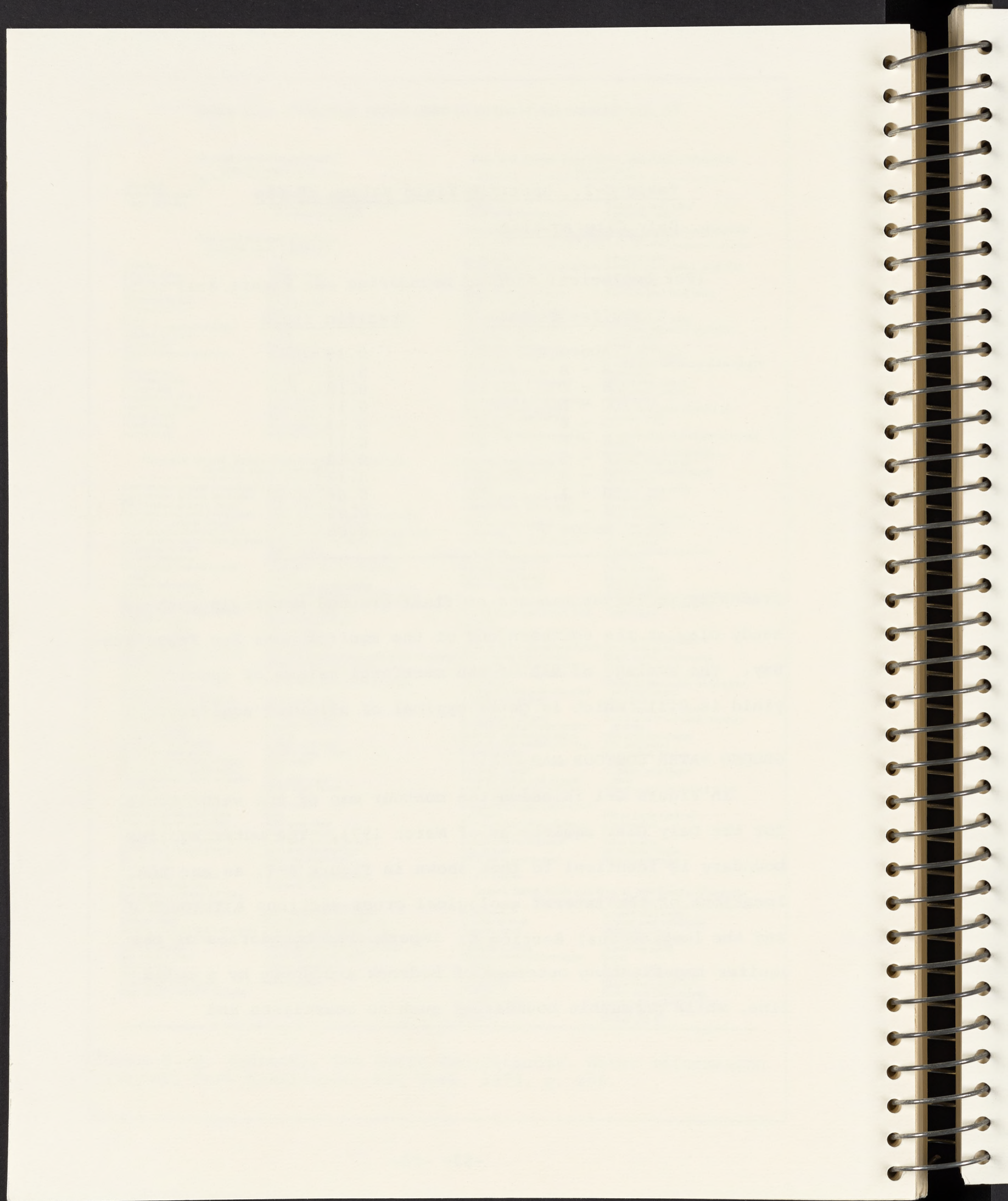
gradually to larger amounts of finer-grained materials such as sandy clay at the southern end of the aquifer near San Francisco Bay. The average of all of the sectional values of specific yield is 0.11, which is quite typical of alluvial aquifers.

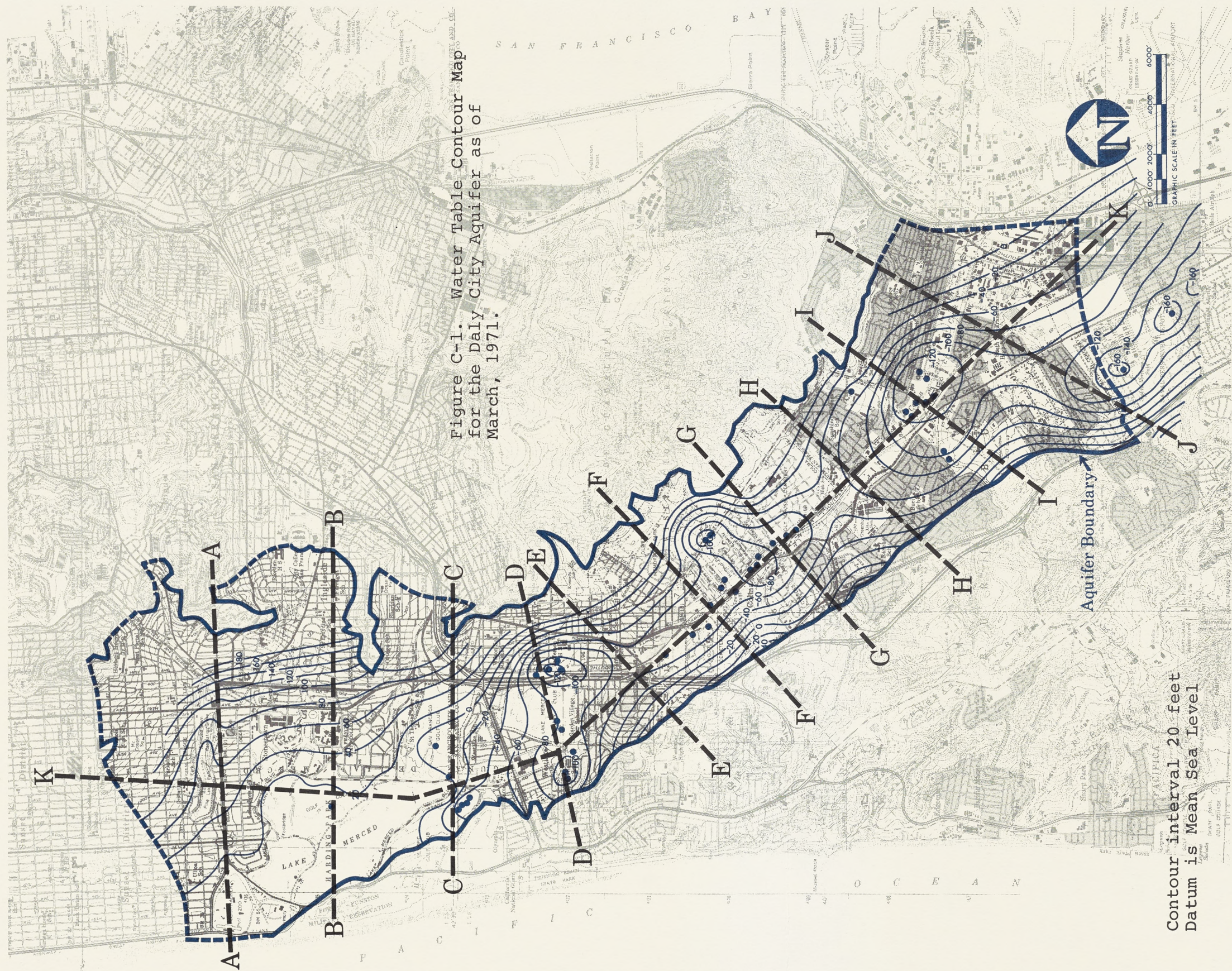
GROUND WATER CONTOUR MAP

In Figure C-1 is shown the contour map of the water table for the Daly City aquifer as of March 1971. The outer aquifer boundary is identical to that shown in Figure A-1, as are the locations of the lateral geological cross-sections A through J and the longitudinal Section K. Impermeable boundaries of the aquifer representing outcrops of bedrock are shown by a solid line, while permeable boundaries such as coastlines and

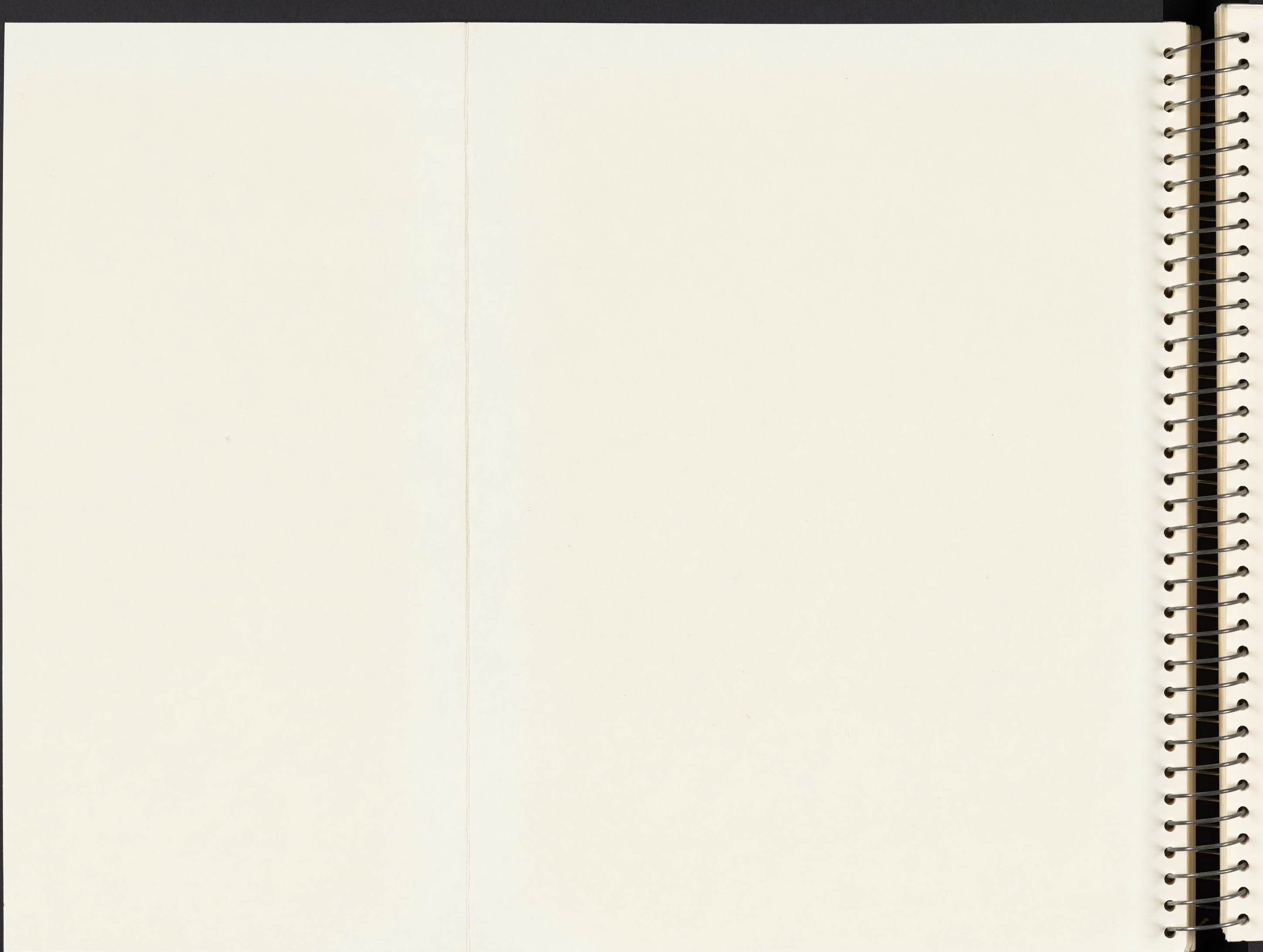








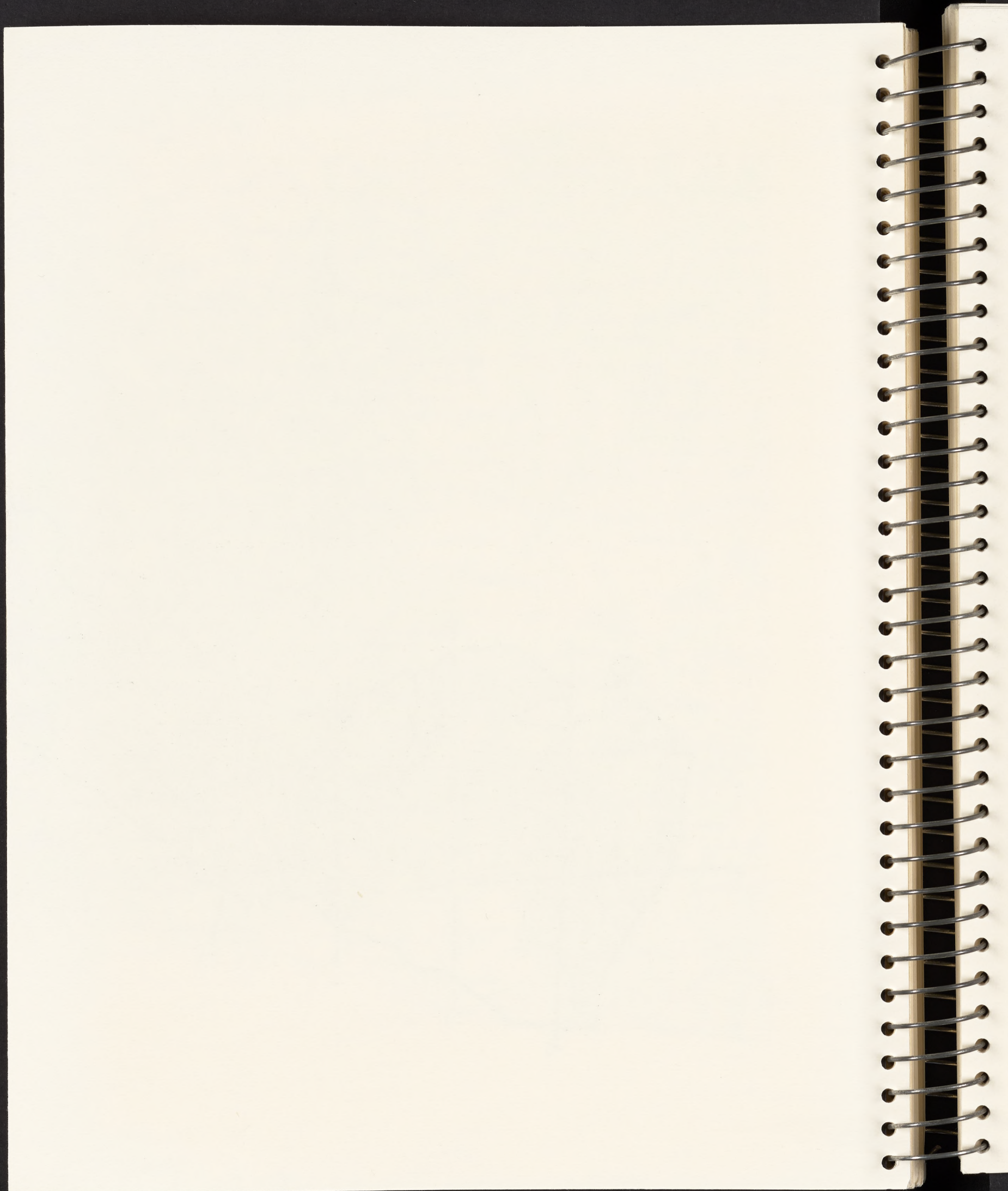
Contour interval 20 feet
Datum is Mean Sea Level



extensions of the aquifer beyond the main basin are shown by a dashed line.

The water table map is based upon water table elevations using mean sea level as a datum. During March 1971 static water levels were measured in 25 of the 47 active wells in the aquifer. Where static levels could not be measured directly, pumping levels were obtained and then corrected to static levels by adding the estimated drawdowns of the wells. In addition, 17 static water levels from previous measurements--several within the last year--were obtained from the well inventory, Table B-1. Thus, only five active wells had no reported measurements. The March 1971 water levels are listed in Table C-3; well numbers correspond to those of the well data in Table B-1.

On the map in Figure C-1 all active wells are indicated by solid circles and contours are drawn at 20-foot intervals. The contour pattern was drawn to correspond not only to static water levels in wells, but also to the known geological and topographical features that would govern the flow of ground water. This use of inference in drawing the contours was important in order to obtain a consistent flow field for the entire aquifer.



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Table C-3. Static Water Levels Measured In
Active Wells of the Daly City Aquifer During
March 1971

<u>Well Number</u>	<u>Static Water Level,</u> <u>Ft, MSL</u>
8	-51.8
19	-118.4
21	-79.5
22	-91.8
23	-92.5
24	-123.7
25	-113.0
26	-136.3
31	-71.0
34	-75.5
35	-65.4
37	-66.7
39	-26.1
43	-90.0
45	-88.9
47	-77.6
56	-127.8
57	-130.4
66	-136.9
69	-162.0
72	-165.3
79	-138.4
82	-144.5
85	+0.3
86	-110.0

GROUND WATER STORAGE VOLUME

The volume of water available in an aquifer equals the gross volume of the aquifer multiplied by the specific yield. For the Daly City aquifer gross volumes were computed by planimetering the effective aquifer cross-sections shown in Figures A-2 through A-11.

Using the specific yield values from Table C-2 and the

aquifer boundaries defined by the sections in Figures A-2 through A-11, volumes of available water were determined for: (a) an assumed maximum water table based upon geological and topographical considerations and no pumping wells; and (b) the existing water table as of March 1971 using the water table map of Figure C-1. The longitudinal cross-section of the aquifer (See Figure A-12) also shows the maximum and existing water table positions as well as the assumed bottom of the productive aquifer.

Table C-4 summarizes the quantities of ground water available by sections in the Daly City aquifer. From the totals it can be seen that past pumpage of the aquifer has depleted 23,900 million gallons of ground water, which amounts to 26 percent of the maximum aquifer storage volume. The loss, however, is not uniformly distributed throughout the aquifer. The maximum depletion, amounting to 38 percent, has occurred between aquifer Sections D and E which is the central portion of Daly City. A secondary maximum of 31 percent loss occurs in the South San Francisco-San Bruno area below Section J.

Table C-4. Volumes of Available Ground

Water in the Daly City Aquifer

Aquifer Section	Volume with Maximum Water Table, million gallons	Volume with March 1971 Water Table, million gallons	Percentage Decrease in Volume
Above A	1,600	1,300	19
A - B	9,600	8,400	12
B - C	8,700	7,600	13
C - D	11,300	7,900	30
D - E	9,000	5,600	38
E - F	8,800	6,200	30
F - G	8,000	5,800	27
G - H	9,400	7,200	23
H - I	5,200	4,000	23
I - J	9,800	7,200	27
Below J	11,800	8,100	31
TOTAL	93,200	69,300	

GROUND WATER FLOW PATTERNS

Examination of Figure C-1 enables considerable insight to be gained as to the flow directions and sources of recharge and discharge of ground water in the Daly City aquifer. Before any wells were drilled in the aquifer, the water table would have been recharged by infiltrating precipitation on the valley floor and by tributary streams draining into the valley from the highlands on each side. As shown in Figures A-2 through A-11, the water table would have sloped toward the center of the valley from each side. Along the length of the valley, ground water would have drained toward the two ends of the aquifer from the center. Thus, in Figure A-12 the highest water table under

assumed maximum conditions (without wells) occurs between aquifer Sections E and F and slopes downward to San Francisco Bay at the southern end and to Lake Merced and the Pacific Ocean at the northern end.

With the presence of wells, however, the original ground water flow pattern becomes significantly distorted. In the vicinity of each concentration of pumping wells, a cone of depression, often thousands of feet in diameter, is formed. Thus, from south to north in Figure C-1, major cones are produced by San Bruno wells, California Water Service Company wells, cemetery wells in and near Colma, and Daly City wells. In addition, a minor cone is created by the wells of the Olympic Golf and Country Club. Some of the cones have multiple low levels (San Bruno, Colma, and Daly City) because of the dispersal of the wells in a general area.

It should be recognized that the large cones of depression shown on Figure C-1 represent static water table elevations produced by continual pumpage of active wells. The actual water table at any instant with all wells in operation would superimpose upon it deep individual cones produced by the drawdown of each well. From the well data (Table B-1) drawdowns of active wells range from as little as 4 feet to as much as 111 feet; the median drawdown is 40 feet. It follows, therefore, that the instantaneous water table surface varies markedly from that shown in Figure C-1 in the immediate vicinity of each

pumping well.

In spite of local importance to well operation of the deep cones of depression around individual pumping wells, the overall pattern of ground water flow and especially the areas of ground water recharge and discharge can best be seen from the static water table map. One important observation from Figure C-1 is that the water table appears clearly to be continuous throughout the aquifer, thereby confirming that the aquifer is a single unconfined unit. Thus, the Colma and Merced formations permit ground water to move freely, indicating that the stratified layers in the Merced formation are not extensive enough to form multiple or confined aquifers. Most of the ground water being pumped today comes from the Merced formation as can be seen from the aquifer cross-sections in Figures A-2 through A-11.

Recognizing that ground water flows perpendicular to the water table contours, recharge of the Daly City aquifer appears to originate primarily from lateral inflow of surface water and ground water. At the northern end, Lake Merced receives ground water draining from the north and east; however, at its southern end water flows from the lake to the Olympic Golf Club wells. According to Figure C-1 the Daly City wells collect water from as far north as San Francisco State College and to a southern limit of about Woodlawn Cemetery. The cemetery wells near Colma take all ground water in the central portion of the

aquifer down to approximately the Colma-South San Francisco city line. The California Water Service Company wells collect all water down to an east-west line through South San Francisco High School and projecting into San Francisco Bay. And finally, the San Bruno wells serve as a focal point for all ground water at the southern end of the aquifer and in the adjoining alluvial aquifer extending southward along the west side of San Francisco Bay.

With regard to sea water intrusion there is no evidence from Figure C-1 that sea water is entering the northern end of the aquifer from the Pacific Ocean. A positive seaward gradient of the water table appears to exist in the Fleishhacker Zoo area to the north of Lake Merced and in the Fort Funston area to the west. The Olympic Club wells are closest to the coast, but they are situated on the western edge of the aquifer and, therefore, should be insulated from any invasion of sea water. These wells derive their water principally from Lake Merced and from the Ingleside and Alemany Boulevard areas of the aquifer to the east.

At the southern end of the aquifer there is a pronounced water table gradient from San Francisco Bay inland to the California Water Service Company and San Bruno well fields. This slope, which amounts to a decline of as much as 165 feet in a distance of 7,000 feet strongly suggests that saline water from San Francisco Bay is moving toward these wells. The fact

that an increase in salinity has not been observed at the wells indicates only that the movement is sufficiently slow so that salt water has not yet reached the wells, but there is no assurance that it will not occur in the future. Undoubtedly, the advance of saline water is slow considering the fact that bay mud underlying San Francisco Bay and the fine-grained materials, such as sandy clay, which predominate at the southern end of the aquifer both are relatively impermeable. Furthermore, the deepest cones of depression are those at the southern end of the aquifer indicating that with the low specific yield values found in this area (See Table C-2), a greater dewatering of the aquifer is necessary to supply the pumpage than for comparable well fields to the north.

As a general observation from Figure C-1, it appears that the various tributary streams and valleys draining into the valley of the aquifer are important sources of ground water recharge. On the west side, for example, the drainage channel west of Colma and Twelvemile Creek farther south both have convex water table contours where they reach the aquifer. On this basis ground water is flowing radially outward into the aquifer from the tributary valleys. The same is true for the large side valley due east of Daly City which drains a significant portion of San Bruno Mountain.

With the predominate role of the well fields in controlling the ground water flow directions, there is little or no flow

through the entire aquifer. One can visualize a zone type of flow distribution with the California Water Service Company-San Bruno wells monopolizing the southern section; the cemetery wells, the central sector; and the Daly City wells, the northern sector. Only in the northernmost portion of the aquifer, roughly north of a line through San Francisco State College and City College of San Francisco, where the aquifer is thin and there are no wells, can it be said that the present day flow pattern is essentially unmodified by effects of pumping wells.

POTENTIAL NEW WELL SITES

If new wells were to be drilled by Daly City, they should be located where the aquifer is deep and permeable and where the least interference with existing wells would be produced. Study of Figure C-1 suggests that the three most promising sites in Daly City are as follows (assuming no problems of ground water quality):

- (a) Northeast of Westlake School and south of the County line;
- (b) South of Washington Drive and near Brown School;
- (c) Between Thornton School and Colma School.

Before constructing new wells at any of these sites, exploratory test holes should be constructed. Assuming that geological conditions are similar to those already known to exist in the general area, well yields comparable to those obtained by existing wells of the City, which are in the order of 300 to 500

gpm, should be expected.

Almost more important than the siting of any new wells for Daly City is the question of the total availability of ground water in the aquifer. This requires analysis of the quantities of ground water recharge and discharge, trends in water table levels, and the safe yield of the aquifer. These topics are described in the following sections of this report.

SECTION D

RECHARGE OF AQUIFER

HYDROLOGICAL WATER BALANCE

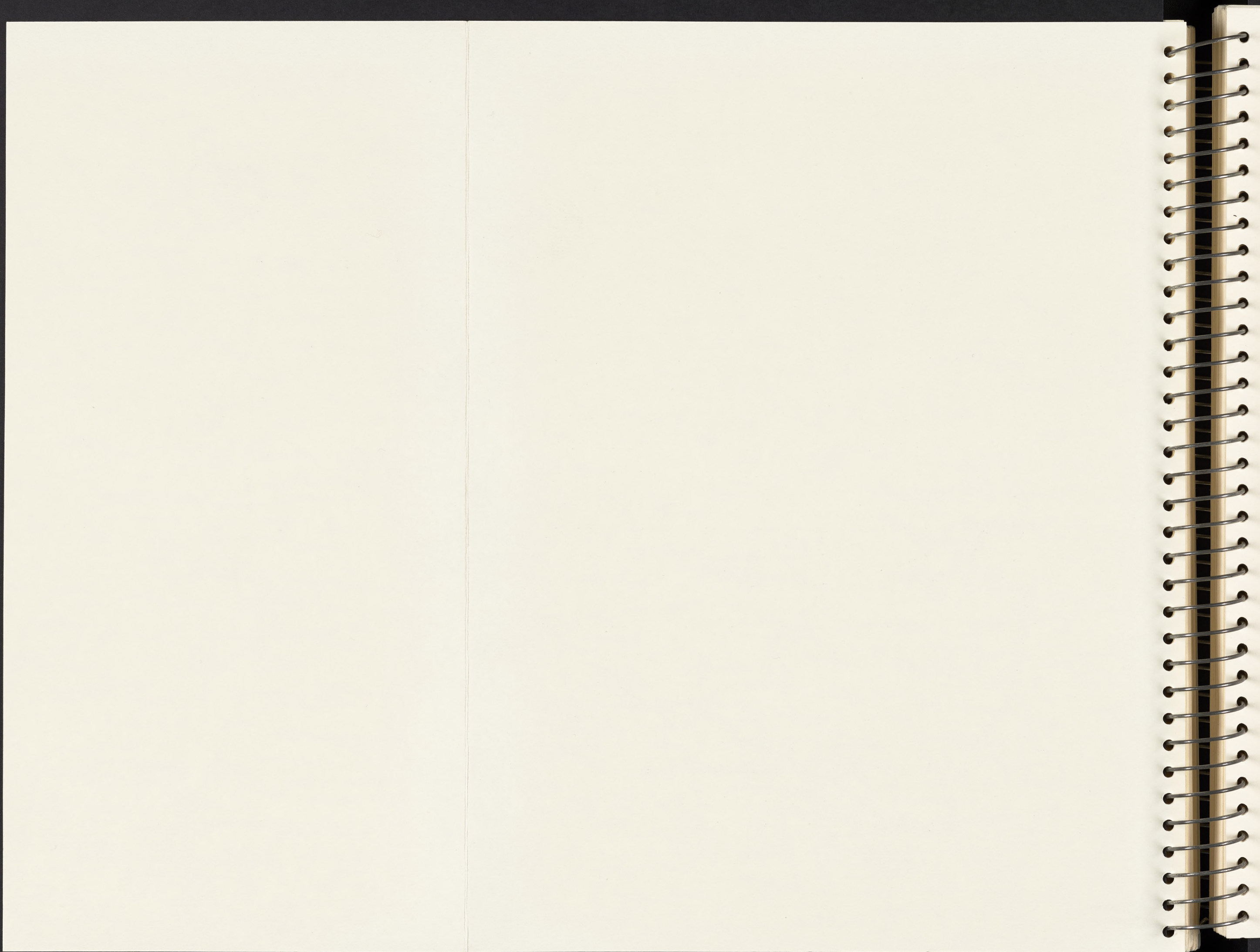
In this section the various components of the hydrological balance equation are analyzed with a view to determining the total amount of water available for recharge to the aquifer. Recharge represents the net volume of water added to the aquifer during a water year and is determined from a hydrological balance equation, which includes items of inflow, precipitation, outflow and consumptive use. This information, together with data on ground water level changes and ground water use, enables an estimate to be prepared of the safe yield of the aquifer.

Tributary Drainage Area. The drainage area for the Daly City aquifer consists of two distinct basins--the Lake Merced Basin to the north and the Colma Creek Basin to the south. The topographical boundaries outlining the two basins, as well as the aquifer area itself, are shown in Figure D-1. It can be noted that the dividing line between the two aquifers occurs in Daly City and is approximately located along a line formed by Lincoln Elementary School, Eastmoor Avenue freeway overpass, and Daly City Reservoir No. 1.

The Lake Merced Basin has an area of 10.2 square miles and extends in an east-west direction from Mount Davidson to the Pacific Ocean and in a north-south direction from the Sunset District of San Francisco to the above-mentioned dividing line.



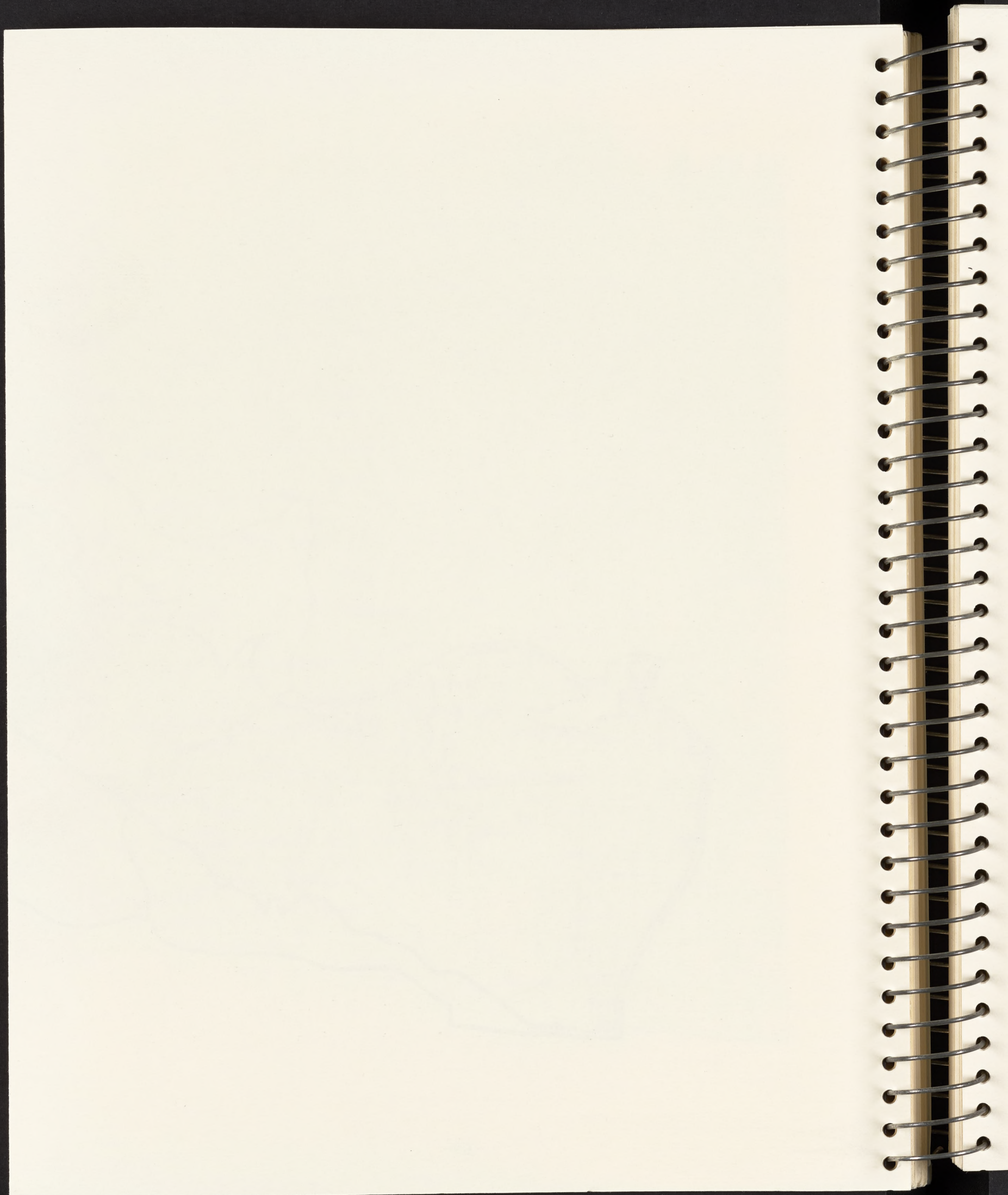
Figure D-1. Map of the Drainage Area of the Daly City Aquifer.



To the east of the basin in the valley occupied by Alemany Boulevard, surface water drains eastward toward San Francisco Bay; however, the underlying bedrock valley slopes downward toward the west. Thus, there is some indeterminate subsurface inflow of ground water into the basin from the east.

The Colma Creek Basin has an area of 14.1 square miles and extends in a northwest-southeast direction from the above-mentioned dividing line to San Francisco Bay and in a northeast-southwest direction from San Bruno Mountain to the ridge of the Santa Cruz Mountains in the vicinity of the San Andreas Rift Zone. The basin has been terminated in Figure D-1 at the Bay-shore Freeway, because beyond this line are tidal mudflats of San Francisco Bay which have been reclaimed as industrial land but which do not properly constitute a part of the basic tributary area. The mudflats are impregnated with sea water from San Francisco Bay and thus are not part of the fresh water drainage system.

Rainfall. To begin an analysis of the annual volume of recharge available in the Daly City aquifer, it is necessary to establish the mean annual rainfall over the tributary drainage area. Examination of Climatological Data for California, published by the U. S. Weather Bureau, reveals that no regularly established U. S. Weather Bureau rainfall stations are located in the aquifer area. Those nearby, as well as two in the area, one operated by the North San Mateo County Sanitation District



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and the other by the San Francisco Water Department, are listed in Table D-1 together with their years of record, values of mean annual rainfall and station elevations.

In addition to the stations appearing in Table D-1, two short-term records are available for rainfall stations established by the U. S. Geological Survey in the Colma Creek Basin. One was located at Christen Ranch (altitude 200 feet and 3,500 feet southwest of Colma) for the period 1961-65, while the other was located at the San Mateo County Maintenance Yard on Collins Avenue (altitude 141 feet and 2,000 feet south of Colma) for the period 1965-67.

Table D-1. Mean Annual Rainfalls for
Stations in and near the Daly City Aquifer

<u>Station*</u>	<u>Years of Record</u>	<u>Mean Annual Rainfall, In.</u>	<u>Elevation, Feet</u>
San Francisco, Federal Bldg.	120	20.78	52
San Francisco, Richmond Sunset	15	18.09	32
San Francisco, Lake Merced	70	20.87	43
Daly City, Westlake	4	22.03	42
San Francisco Weather Bureau, Airport	42	18.69	8
Burlingame	24	17.97	10
San Mateo	77	20.77	21

*All stations are operated by the U. S. Weather Bureau except San Francisco, Lake Merced by the San Francisco Water Department and Daly City, Westlake by the North San Mateo County Sanitation District.

Because of the short period of record of these two nearby stations, monthly rainfalls at the stations were correlated by the U. S. Geological Survey with those of the San Francisco Airport. The result, shown in Figure D-2, suggests that the rainfall at each site was essentially equal to the airport values for the period 1963-67.

The difficulty in attempting to interpolate an area-wide rainfall value from the above data is that they do not represent fully conditions within the basin. All seven stations in Table D-1 are located at relatively low elevations, yet rainfall in the San Francisco Bay area may be significantly correlated with elevation. Thus, the drainage area elevations rising to 1,314 feet on San Bruno Mountain and to 760 feet on the Santa Cruz Range could produce important modifications in the magnitude of rainfall occurring over the area.

To provide a better areal estimate of rainfall, an isohyetal map of the San Francisco peninsula was prepared; the portion covering the Daly City aquifer drainage area is shown in Figure D-3. This was drawn on the basis of measured rainfalls at stations in the general area and was supplemented by extrapolations based on regional topography.

By planimetry it was determined that the mean annual rainfall for the Lake Merced Basin is 23.4 inches and for the Colma Creek Basin is 26.0 inches. It should be recognized that areal rainfall in any given year may differ markedly from

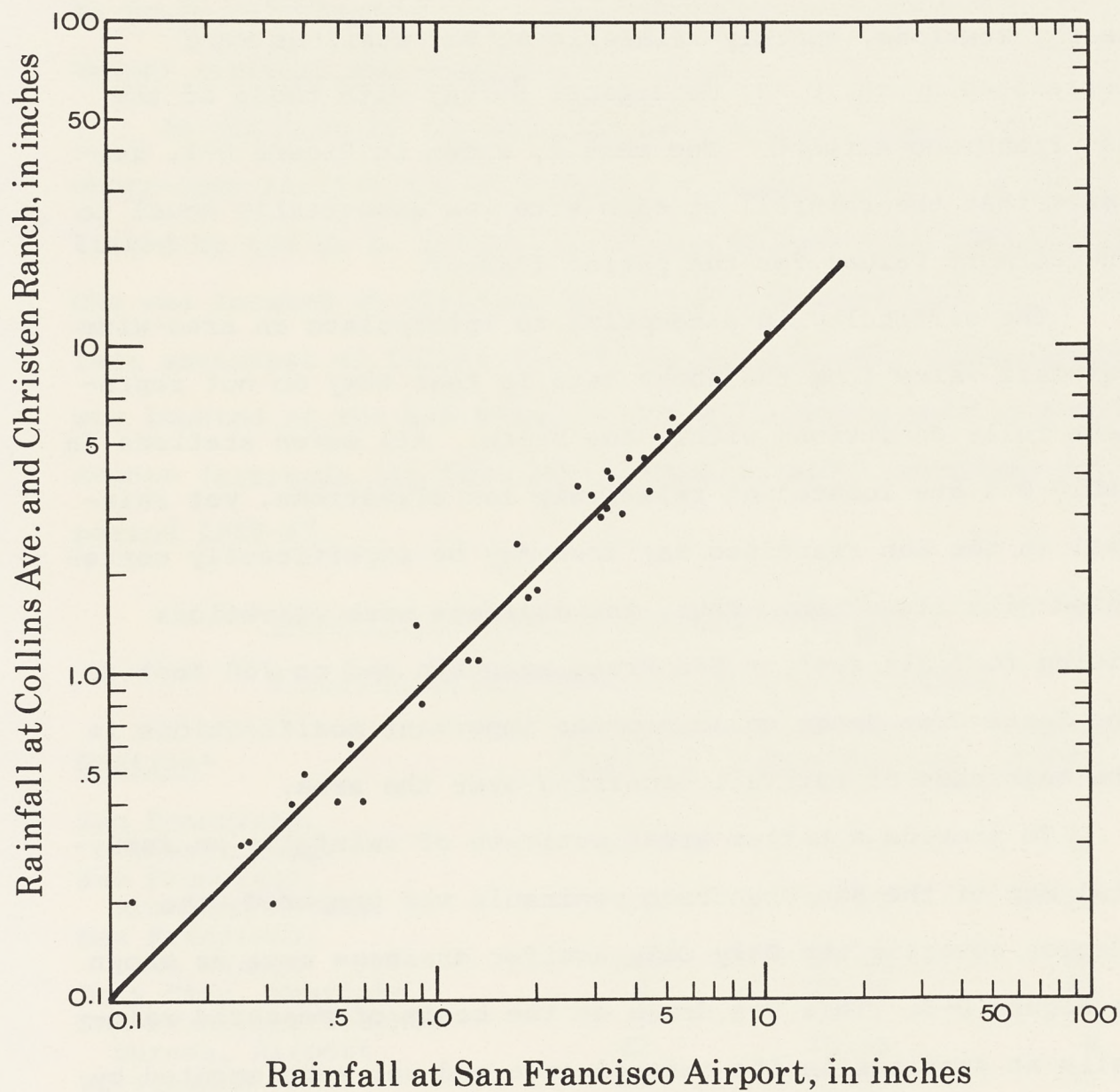
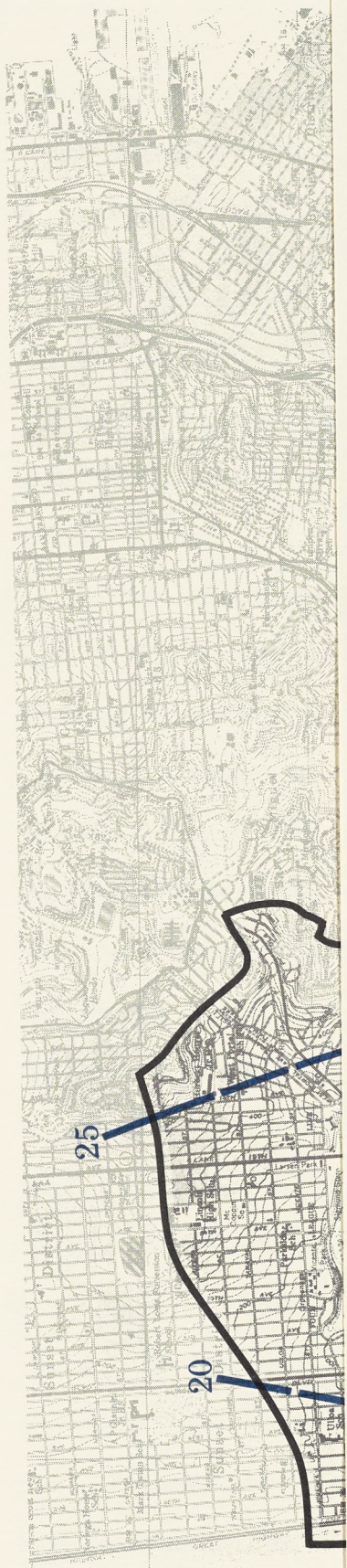


Figure D-2. Relation of Rainfall at Collins Avenue and Christen Ranch to That at San Francisco Airport for Concurrent Months during the Water Years 1963-67.



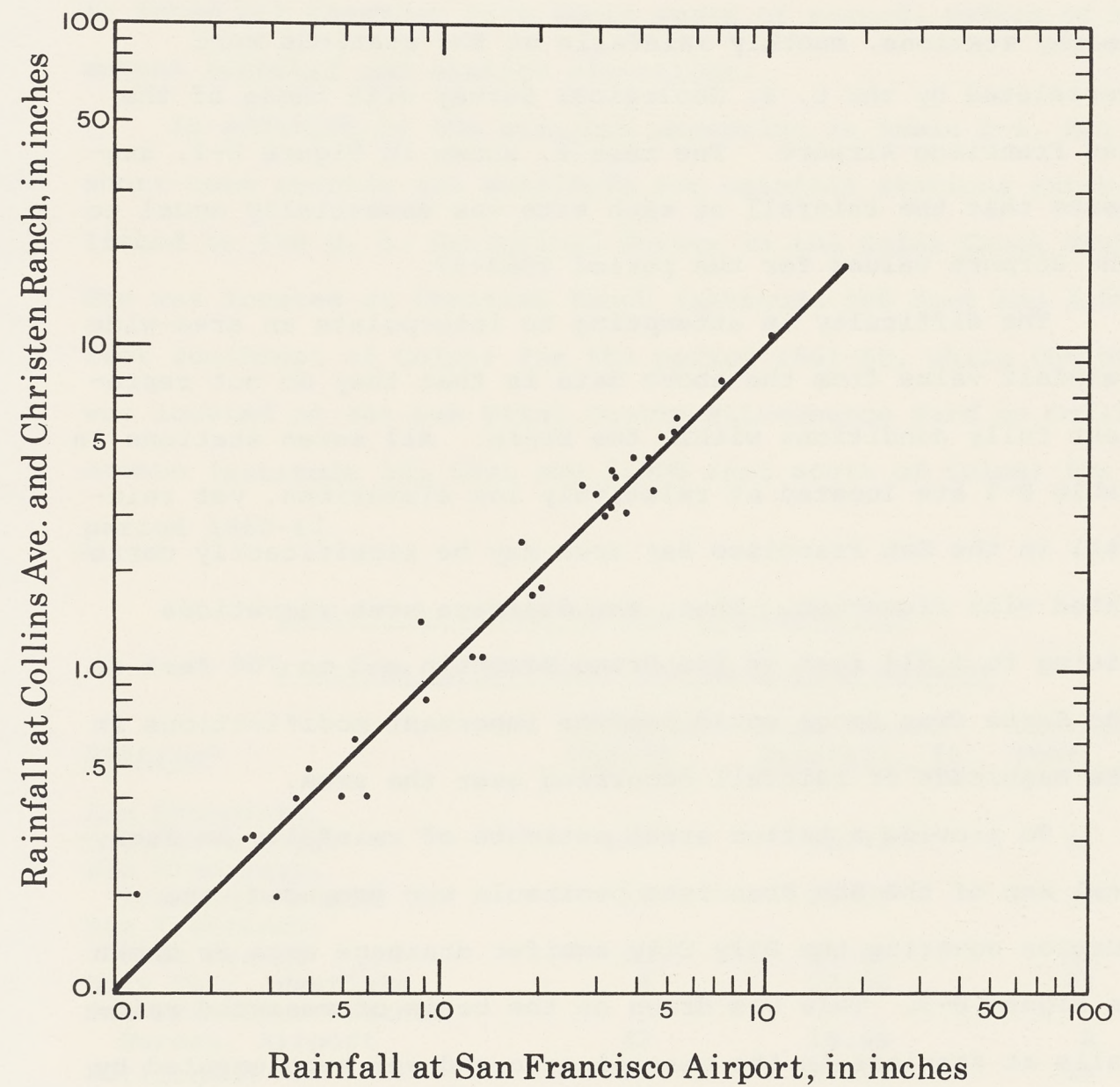
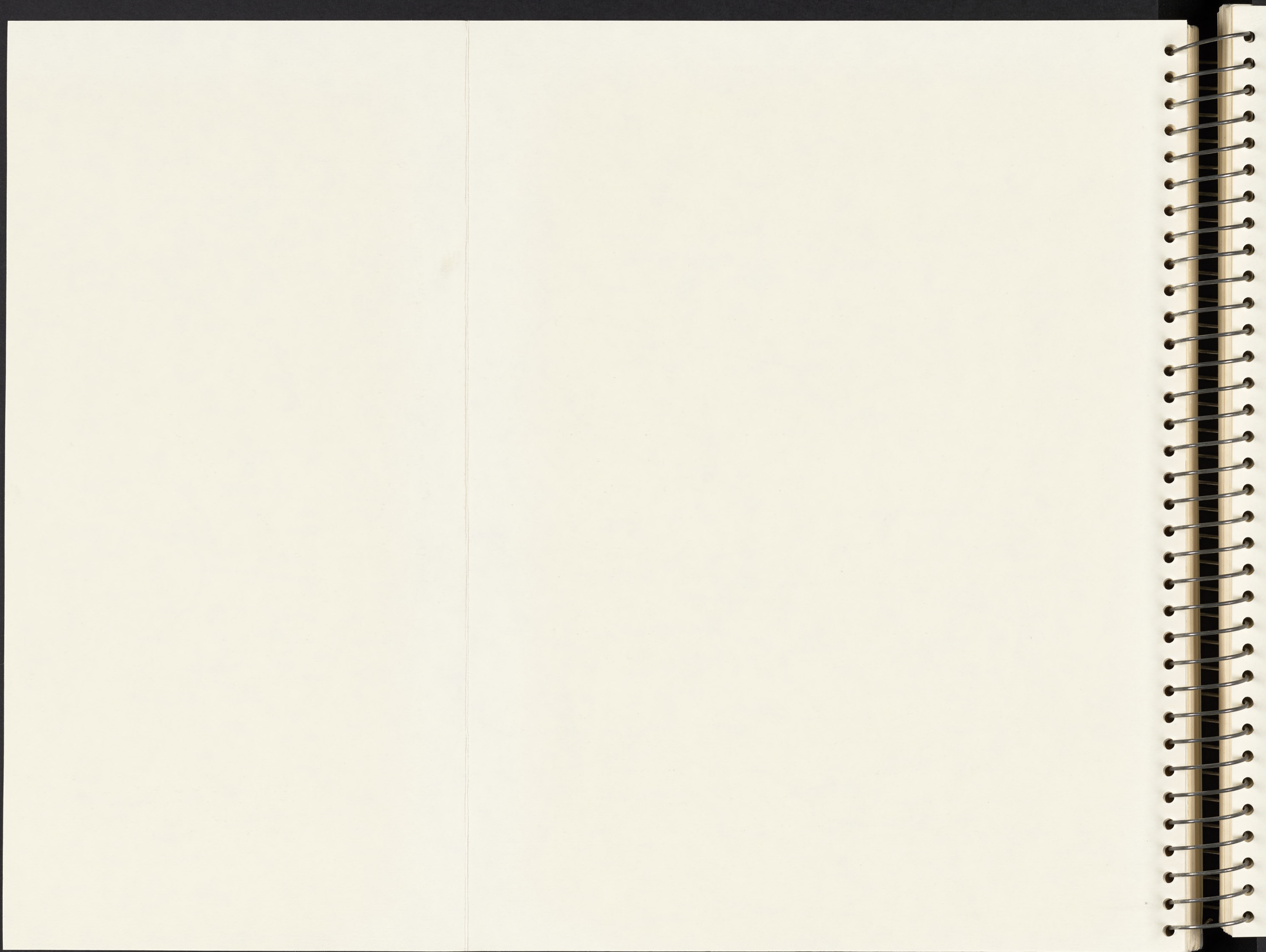


Figure D-2. Relation of Rainfall at Collins Avenue and Christen Ranch to That at San Francisco Airport for Concurrent Months during the Water Years 1963-67.



Figure D-3. Isohyetal Map of Mean Annual Rainfall over the Daly City Aquifer Drainage Area.

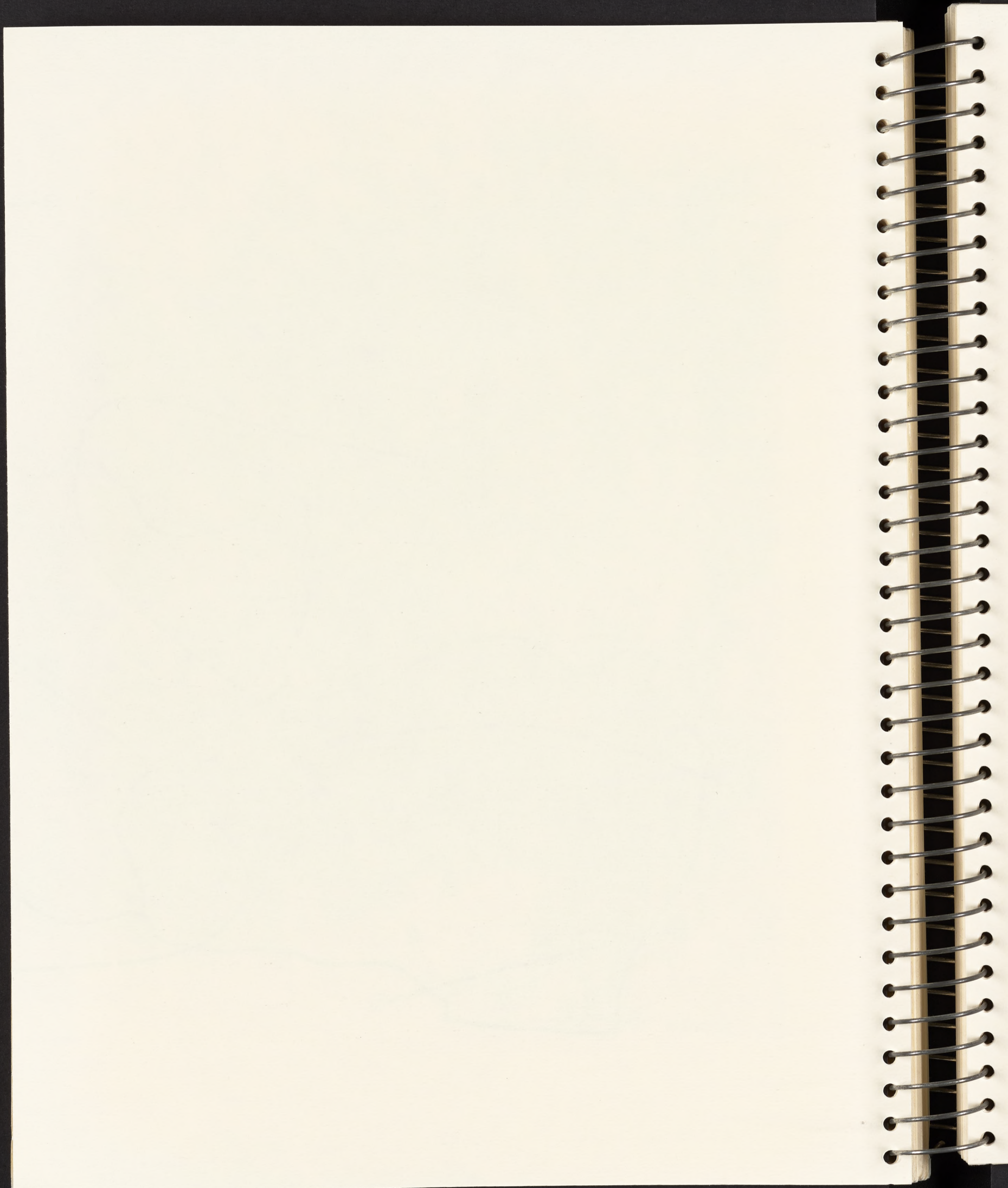


the mean; however, in terms of total ground water resources, the mean furnishes a good index of the long-time supply of water to a drainage area.

Colma Creek Outflow. There is no appreciable regulation of streamflow in Colma Creek Basin. High flows, however, are affected by several debris basins in the western highlands, while low flows are augmented by return flow from urban and agricultural areas.

Two short records of streamflow exist in Colma Creek Basin. One station was established in late 1963 on Colma Creek in Orange Memorial Park of South San Francisco. Its drainage area of 10.9 square miles includes most of the highland and urban areas. The other gaging station was established in early 1965 on Spruce Branch, a northward-draining tributary of Colma Creek, in the vicinity of the intersection of Spruce Avenue and the Southern Pacific Railroad. The 1.68 square mile drainage area upstream from the Spruce Branch Station is highly urbanized. Together, the two gaging stations have a drainage area of 12.58 square miles, which amounts to about 89 percent of the total Colma Creek Basin.

The streamflow record at Colma Creek was extended by the U. S. Geological Survey for the period 1953-63 on the basis of correlation with Matadero Creek of Palo Alto. The correlation was determined from frequency curves of daily mean discharge for the water years 1964-67. The annual discharges of Colma Creek



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at South San Francisco are listed in Table D-2. It should be noted that a large variation in annual streamflow occurred during the period 1953-67 with values ranging from 300 to 9,700 acre-feet. The 1965-67 record of annual streamflow for Spruce Branch at South San Francisco is listed in Table D-3.

On the basis of the above records an estimate of the mean annual discharge from the entire Colma Creek Basin can be made. The mean for the area above Colma Creek gage is 3,200 acre-feet from Table D-2. For the Spruce Branch drainage area an estimate of the mean can be obtained by applying the ratio of 1966-67 streamflows to the mean flow at Colma Creek gage. This gives a mean flow for Spruce Branch of 720 acre-feet. Summing the two means and multiplying by the factor $1.00/0.89$ to obtain the runoff for the entire Colma Creek Basin yields a mean annual streamflow of 4,400 acre-feet.

Lake Merced Basin Outflow. There are no streamflow records available in the Lake Merced Basin. Most surface runoff is carried by a system of storm sewers to the Pacific Ocean.

Imported and Exported Water. Importations of water into the Daly City aquifer area occur from the Hetch Hetchy system as the San Francisco Water Department furnishes water either wholly or in part to all cities and towns in San Mateo County. Because this water is relatively expensive, it is used almost entirely for municipal and urban purposes. Local sources of water are generally developed first, while the San Francisco water is employed primarily for supplemental and peaking purposes as required.

Table D-2. Discharge of Colma Creek

at South San Francisco

(Drainage area = 10.9 sq. mi.)

<u>Water Year*</u>	<u>Annual Total Streamflow, Acre-feet**</u>
1953	3400
1954	300
1955	1300
1956	7700
1957	360
1958	9700
1959	1300
1960	1100
1961	440
1962	2200
1963	3600
1964	1690
1965	4060
1966	3360
1967	7220
Mean 1953-67	3200

* October 1 to September 30.

** Discharges for the period 1953-63 were estimated on the basis of correlation of Colma Creek at South San Francisco with Matadero Creek at Palo Alto for the period 1964-67.

Table D-3. Discharge of Spruce Branch

at South San Francisco

(Drainage area = 1.68 sq. mi.)

<u>Water Year</u>	<u>Annual Total Streamflow, Acre-feet</u>
1966	825
1967	1470

There are no facilities for transporting water from the Daly City aquifer for use elsewhere; however, sanitary and storm sewers discharge water from the area into the Pacific Ocean and San Francisco Bay.

Consumptive Use. Water that is physically consumed so that it is no longer directly available is referred to as consumptive use. This water is in most instances transformed into vapor and becomes part of the earth's hydrological cycle. Water is released into the atmosphere by evaporation (a direct change of state from liquid to vapor form) from the soil, ground and building surfaces, puddles, vegetation, streams, lakes and reservoirs. The most important controlling factors of evaporation are temperature, vapor pressure, wind and radiation.

Water is also released by transpiration (vapor emitted from the leaves of growing plants), which occurs from trees, grass, weeds, irrigated crops and all other forms of vegetation. The same factors governing evaporation also apply to transpiration and, in addition, light. Both evaporation and transpiration have well defined diurnal and seasonal fluctuations.

Consumptive use varies, of course, with the type of land use. In urban areas where a major fraction of the water is used for domestic and municipal purposes (bathing, washing, cleaning, cooling, air conditioning and toilets), the consumptive use is relatively small. Most of the water is discharged as wastewater into the ocean. In San Mateo County sanitary waste discharges

average 70 gallons per person per day.

Procedures for determining areal consumptive use are based either on detailed hydrological balances for an entire drainage basin or upon computations using the Blaney-Criddle or the Thornthwaite consumptive use formulas. For the Daly City aquifer area an estimate of consumptive use can be made from a knowledge of the climate and of areas and types of land use, supplemented by determinations of consumptive use on urban and rural areas elsewhere in California.

As a starting point the maximum value of consumptive use is approximately equal to the evaporation from a free water surface. Studies by the California Department of Water Resources for San Mateo County indicate a mean evaporation as given in Table D-4. The actual consumptive use from a given land use area depends largely upon the quantity of water supplied. For an irrigated grassland, such as a country club, the rate approaches that of evaporation, but for an urban area supplied with only limited water, the rate will be materially less. Table D-5 summarizes consumptive use rates estimated for the Daly City aquifer drainage area.

Table D-4. Mean Monthly Evaporation
from Water Surfaces in San Mateo County

<u>Month</u>	<u>Evaporation Rate, Inches</u>
January	0.84
February	1.21
March	2.40
April	3.60
May	4.32
June	6.12
July	6.00
August	5.76
September	4.56
October	3.00
November	1.68
December	0.84
<u>Annual Total</u>	<u>40.33</u>

Table D-5. Estimated Mean Annual
Consumptive Use Values for the
Daly City Aquifer Drainage Area

<u>Land Use</u>	<u>Consumptive Use, Feet/Year</u>
Urban	1.5
Lake	3.3
Country club	3.2
Cemetery	3.2
Upland--San Bruno	
Mountain	1.5
Upland--Santa Cruz	
Range	1.6

For comparative purposes the mean consumptive use for San Fernando Valley, an extensive highly-urbanized area in Los Angeles County, was computed as 1.87 feet per year. Such a value is not unreasonable for the Daly City aquifer area and corresponds well with the values assigned to various land use

types in Table D-5.

Hydrological Water Balance in Summary. Having determined the values of the various components of the hydrological balance equation consisting of: 1. Inflow, obtained from consideration of tributary drainage areas, rainfall, and imported and exported water; 2. Outflow, from a study of streamflow records; and 3. Consumptive Use, from studying climatic data and land use; estimates of the aquifer recharge can now be prepared.

WATER BALANCE FOR LAKE MERCED

An important consideration in analyzing aquifer recharge, particularly for water supplying the Daly City wells, is the influence of Lake Merced. This 320-acre lake located directly north of Daly City could potentially be a major source of water. The effect of Lake Merced on ground water recharge is approached from a water balance standpoint and by study of ground water flow directions.

Although there are no streamflow records available in the Lake Merced Basin, an approximate water balance for Lake Merced, however, can be evaluated because the San Francisco Water Department has made measurements over a period of years of water levels at Lake Merced, of water releases into Lake Merced, and of rainfall at a nearby station. The hydrological balance equation has the form:

$$\text{Ground Water Inflow (GWI)} + R + I - E - P - \Delta S = 0$$

where GWI = net ground water inflow into the lake

R = rainfall over the lake

I = imported water released into the lake

E = evaporation from the lake surface

P = net pumpage from the lake for irrigation of
Harding Park, and

ΔS = change in volume of water stored in Lake Merced.

The above equation assumes no inflow or outflow of surface water. With the system of storm sewers in the vicinity of Lake Merced, little direct surface water reaches the lake. Some storm water inflow occurs occasionally during peak rainfalls when the Colma Tunnel reaches its limit, causing backwater to cross Lake Merced Boulevard and thus reach the lake. Furthermore, because of a net deficiency of water generally in the lake, surface overflow, if any, should be a negligible quantity on an annual basis.

The variables in the above equation were determined on a water year basis for the five-year period 1965-70; all quantities were computed in feet of water over the 320-acre area of Lake Merced. The numerical values for each of the years are listed in Table D-6. Note that evaporation is constant and equal to that given in Table D-4. Values for individual years were not available, but because evaporation does not vary widely from year to year, errors involved should not be large. Similarly, for net pumpage, ten years of records were available on a fiscal year but not on a water year basis. As nine of

the ten values fell within 25 percent of the mean, the mean pumpage was assumed to apply for each water year. The mean amounted to a depth of 1.30 feet per year.

The results in Table D-6 show that there has been a mean inflow of ground water to Lake Merced amounting to 2.15 feet per year, which is equivalent to 688 acre-feet per year, or 223 million gallons per year.

Table D-6. Annual Water Balance for Lake Merced

(All values are in feet of water per year over the 320-acre surface area of Lake Merced.)

Water Year	Rainfall +	Imported Water +	Evaporation -	Net Pumpage -	Storage Change -	Ground Water Inflow
1965-66	1.50	0.98	3.37	1.30	(-0.39)	+1.80
1966-67	2.58	0.49	3.37	1.30	(+0.67)	+2.27
1967-68	1.27	0.00	3.37	1.30	(-1.67)	+1.73
1968-69	2.18	0.85	3.37	1.30	(+1.34)	+2.98
1969-70	1.78	0.00	3.37	1.30	(-0.90)	<u>+1.99</u>
Mean						<u>+2.15</u>

It should be recognized from the flow patterns shown in Figure C-1 that ground water enters Lake Merced from the north and east and re-enters the aquifer along the southwestern shoreline to supply the Olympic Golf Club wells. Thus, the mean inflow computed in Table D-6 is a differential quantity, being the amount that ground water inflow exceeds ground water out-flow.

The above analysis demonstrates that there is a net loss

of ground water into Lake Merced, and furthermore, that there is no direct flow of ground water from the lake to Daly City wells. As a result aquifer recharge for Daly City wells occurs south of and hydraulically separate from the ground water tributary area of Lake Merced.

AQUIFER RECHARGE

General. Evaluation of aquifer recharge must be done on the basis of the type of land use because the consumptive use of water varies with land use. In general, recharge represents a very small portion of the total water reaching a watershed. Thus, in Colma Creek Basin the mean rainfall equals 2.20 feet per year and streamflow amounts to approximately 0.50 feet per year (4,400 acre-feet/14.1 sq. mi. x 640 acres per sq. mi. = 0.49 ft.). This leaves a difference of 1.70 feet per year, but most of this, as indicated by Table D-4, is consumed by evapotranspiration; hence, only a minor fraction of the water is available for ground water recharge over the aquifer area.

Aquifer recharge depends upon the infiltration and percolation of surface water. The area contributing recharge must be pervious so that water can freely enter the ground. In developed areas, roofs, sidewalks, and paved surfaces prevent water entering the ground; instead the water becomes storm runoff and is removed from the area by storm sewers. For this study the percentages of pervious areas for various categories of urban land use were defined. This was done for the largest or most critical

land use areas by selecting a typical sample area from an aerial photograph and actually measuring the pervious and impervious areas to obtain the percentage of pervious area. For other land use areas, the percentage of pervious area was determined by visually comparing pervious with impervious. The results, summarized in Table D-7, show the percentages of pervious land available for the types of land use found in the Daly City aquifer area. It can be seen that only a minor fraction of land devoted to commercial, industrial and residential purposes is available for recharge, while areas of parks, golf courses and cemeteries represent zones with substantial availability of land for recharge.

Table D-7. Pervious Areas Available for
Recharge for Various Types of Land Use in
the Daly City Aquifer Area

<u>Land Use</u>	<u>Pervious Area, Percent</u>
Commercial and industrial	10
Residential	30
Schools	60
Cemeteries	70
Parks	75
Golf courses	85
Agricultural	90
Undeveloped	95

Sufficient data is not available to define quantitatively the recharge for the entire aquifer; however, information to determine that recharge supplying the Daly City wells (plus the

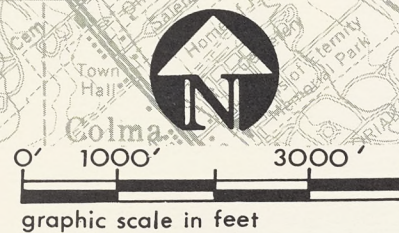
Merced Country Club wells) was available and this computation follows.

Recharge of Daly City Wells. To gain a quantitative estimate of aquifer recharge for the Daly City wells, the drainage tributary area to the ground water aquifer supplying the wells was determined from Figure C-1. A map of this tributary area is shown in Figure D-4. The two Lake Merced Country Club wells were of necessity included in the area because of their central location within Daly City. It should be noted that Wells 27, 28, 29 and 30 are also within this tributary area, but all of these have been abandoned. The northern boundary of the area is a flow line; north of this line ground water moves toward the San Francisco and Olympic Golf Club wells and Lake Merced. The eastern and western boundaries are the limits of the aquifer. Note that there is an undetermined contribution of ground water through a portion of the eastern boundary (shown by a dotted line) draining water from the subsurface valley extending to the east of the aquifer area. The southern boundary again is a flow line; south of this line ground water flows toward the various Colma cemetery wells.

A mean annual rainfall of 24 inches was estimated over this area (See Figure D-3). Using the mean monthly rainfall distribution recorded at San Francisco Airport and adjusting it to an annual total of 24 inches, the monthly rainfall distribution plotted in Figure D-5 was obtained.

Also plotted on Figure D-5 are values of mean monthly evaporation from Table D-4. It is clear that monthly rainfall and

Figure D-4. Map of Daly City Ground Water Tributary Area and Ground Water Flow Directions.



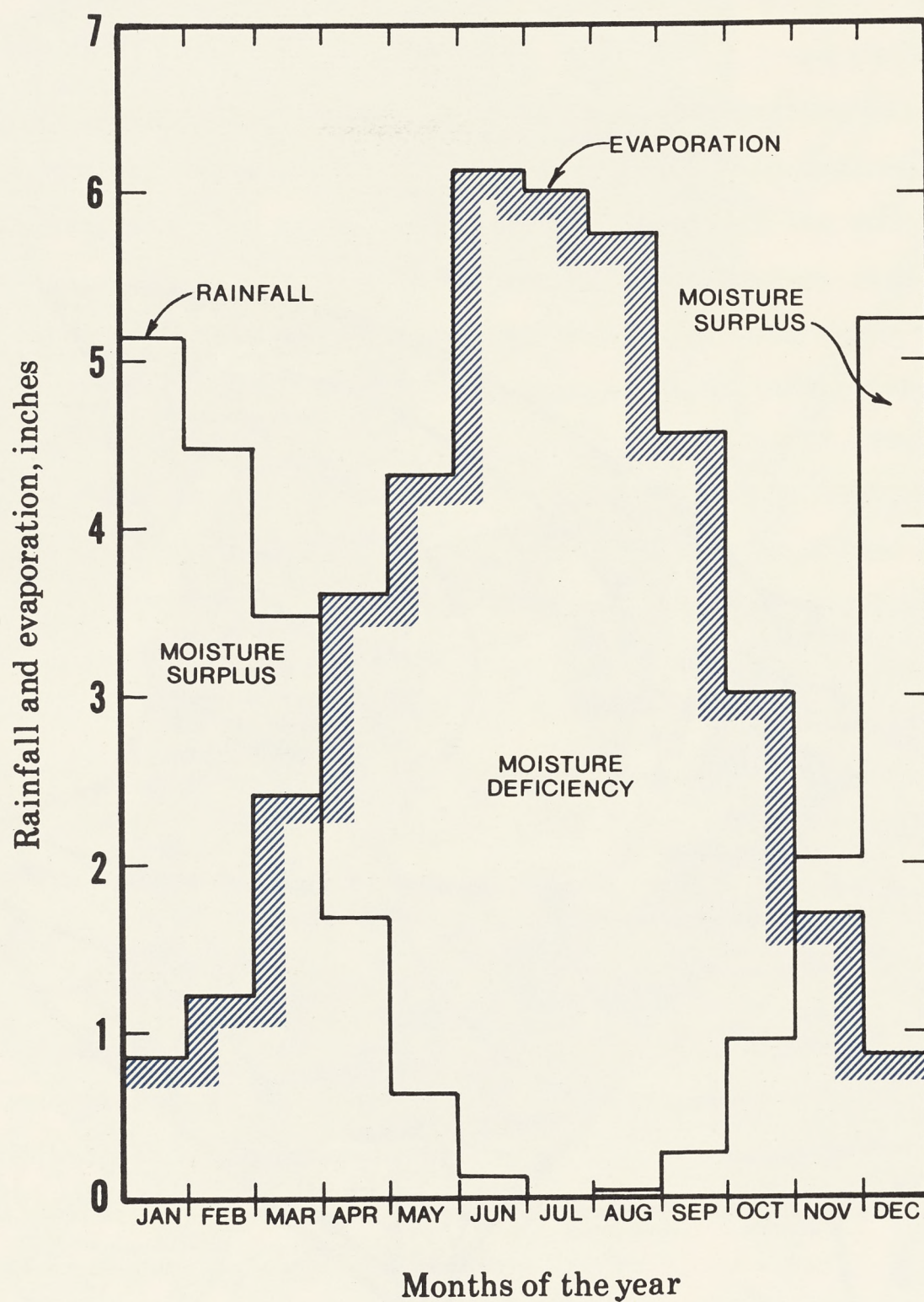


Figure D-5. Monthly Variation of Mean Rainfall and Evaporation in the Daly City Aquifer Area.

evaporation are completely out of phase--summer has low rainfall and high evaporation, while winter is the reverse. A moisture surplus exists for the period when rainfall is greater than evaporation (November-March), but a moisture deficiency occurs for the April-October period when evaporation exceeds rainfall.

Any aquifer recharge must occur during the months of November through March. For these months, a total mean moisture surplus of 13.4 inches is obtained.

The quantity of aquifer recharge supplying the Daly City wells was determined by planimetering the areas of various land uses for the area shown in Figure D-4 and applying the appropriate percentages of pervious area from Table D-7. Details are tabulated in Table D-8, which shows that of the total ground water tributary area of 1,830 acres, only 820 acres, or 45 percent, supply water to the underground.

Table D-8. Pervious Area of the Ground
Water Tributary Area to Daly City Wells

<u>Land Use</u>	<u>Area, Acres</u>	<u>Pervious Area, percent</u>	<u>Pervious Area, Acres</u>
Commercial and industrial	35	10	4
Residential	1340	30	402
Schools	86	60	52
Cemeteries	8	70	56
Parks	70	75	52
Golf courses	223	85	190
Agricultural	10	90	9
Undeveloped	58	95	55
TOTAL	1830		820

To compute the aquifer recharge the pervious area should be multiplied by the mean moisture surplus of 13.4 inches less water retained by the upper soil zone. As a reasonable estimate of soil water retention, two feet of soil having a specific capacity of 0.20 will hold 0.4 feet, or 5 inches, of water. This water would accumulate in the upper soil zone during the winter rainy season and, being held by capillary forces, would not migrate downward to the water table. However, during the following spring and summer periods of moisture deficiency, this water would be released by evaporation and transpiration to the atmosphere.

Thus, the mean annual aquifer recharge is given by

$$\begin{aligned} Q &= 820 \text{ acres} \times (13.4 - 5) \text{ inches} \\ &= 574 \text{ acre-feet per year} \\ &= 186 \text{ million gallons per year} \end{aligned}$$

Thus, the recharge rate to the portion of the Daly City aquifer supplying Daly City and Lake Merced Country Club wells is 186 million gallons per year.

The interpretation of this aquifer recharge rate for the Daly City wells is included in Section E with the safe yield of the aquifer.

SECTION E

SAFE YIELD OF AQUIFER

FACTORS GOVERNING SAFE YIELD

Safe yield of an aquifer may be defined as the maximum quantity of water which can be withdrawn annually without producing an undesired result. Pumpage in excess of safe yield is referred to as overdraft.

The concept of safe yield rests on the idea of ground water being a renewable natural resource and not subject to irreplaceable loss as for oil, gas, gold, and other minerals. An aquifer is essentially a large underground reservoir which, analogous to a surface reservoir back of a dam, produces the greatest benefits when it is properly managed. A reservoir maintained full at all times provides little or no benefits, nor does a reservoir kept empty at all times; however, one that can be filled and drawn down to meet various needs produces optimal results.

Proper management of aquifers produces other important advantages. Typically, aquifers are much larger in volume and far less costly than surface water reservoirs. Ground water stored in them is automatically distributed from the point of recharge to the point of extraction, evaporation is prevented, quality of water is protected, and water temperatures are maintained essentially constant.

The undesired results included in the definition of safe

yield can involve one or more of the following:

1. Depleted supply--If pumpage exceeds recharge on a long-time mean annual basis, permanent depletion (often referred to as "mining") of the ground water will occur.
2. Uneconomic supply--If ground water levels are so lowered as to increase the costs of wells, pumps, and power, a situation can develop such that it is no longer economically feasible to use ground water as a water supply source.
3. Degradation of quality--If pumpage from a basin produces ground water of inferior quality, which could occur from sea water intrusion, from pumping of underlying connate brines, or from drawing poor quality water into the aquifer from adjacent areas, recommended standards of water quality (See Section F) could be exceeded.
4. Interference with water rights--If legal rights to ground water of adjoining property owners are adversely affected by pumpage, legal restrictions or court actions could be initiated.
5. Land subsidence--If excessive pumping lowers ground water levels in regions of thick fine-grained geologic formations, soil compaction, leading to land subsidence, can result.

Although the above listing suggests that a variety of problems can define the safe yield of an aquifer, the first item, available water supply, will govern in most instances. Typically, when pumpage exceeds recharge, other undesired results will be induced. Thus, quantitative determination of safe yield where water supply is the limiting factor can be made where information on recharge and pumpage of the aquifer is available.

EXISTING PUMPAGE

Data on pumpage of the Daly City aquifer is available in terms of water extractions by the City of Daly City, by the California Water Service Company, and by all pumpers from the entire aquifer. For the City of Daly City, records of water use extend back to 1943, although the record is not complete. Table E-1 lists annual volumes of water pumped by the City and purchased by the City from the San Francisco Water Department. These same data, plotted in Figure E-1, illustrates three important points. First is that the total demand for water by the City has grown steadily and dramatically, amounting to an increase by a factor of 12 in 27 years. The second point is that the fraction of the total water demand derived from the aquifer has steadily decreased. Thus, as indicated in Figure E-1, the percentage pumped has dropped from 100 percent during the 1943-46 period to 64 percent in 1970. The third point is that the total volume of ground

Table E-1. Annual Volumes of Water

Pumped and Purchased by the City of

Daly City, 1943-70

(All values in million gallons per year.)

<u>Year</u>	<u>Well Pumpage</u>	<u>Purchased</u>	<u>Total</u>
1943	216.5	0	216.5
1944	224.1	0	224.1
1945	222.8	0	222.8
1946	264.8	0	264.8
1947	M*	M	287.6
1948	M	M	302.8
1949	M	M	340.0
1950	M	M	359.5
1951	M	M	369.3
1952	M	M	386.6
1953	M	M	417.0
1954	M	M	M
1955	M	M	906.4
1956	879.6	49.0	928.6
1957	M	15.9	M
1958	M	6.3	M
1959	M	203.5	M
1960	M	76.1	M
1961	1531.4	99.6	1631.0
1962	1493.9	168.5	1662.4
1963	1678.7	34.0	1712.7
1964	1648.6	85.4	1734.0
1965	1644.8	252.5	1907.3
1966	1609.3	386.7	1996.0
1967	1599.3	527.8	2127.1
1968	1625.4	664.1	2289.5
1969	1654.9	836.9	2491.8
1970	1609.4	910.8	2520.2

* M = Data missing.

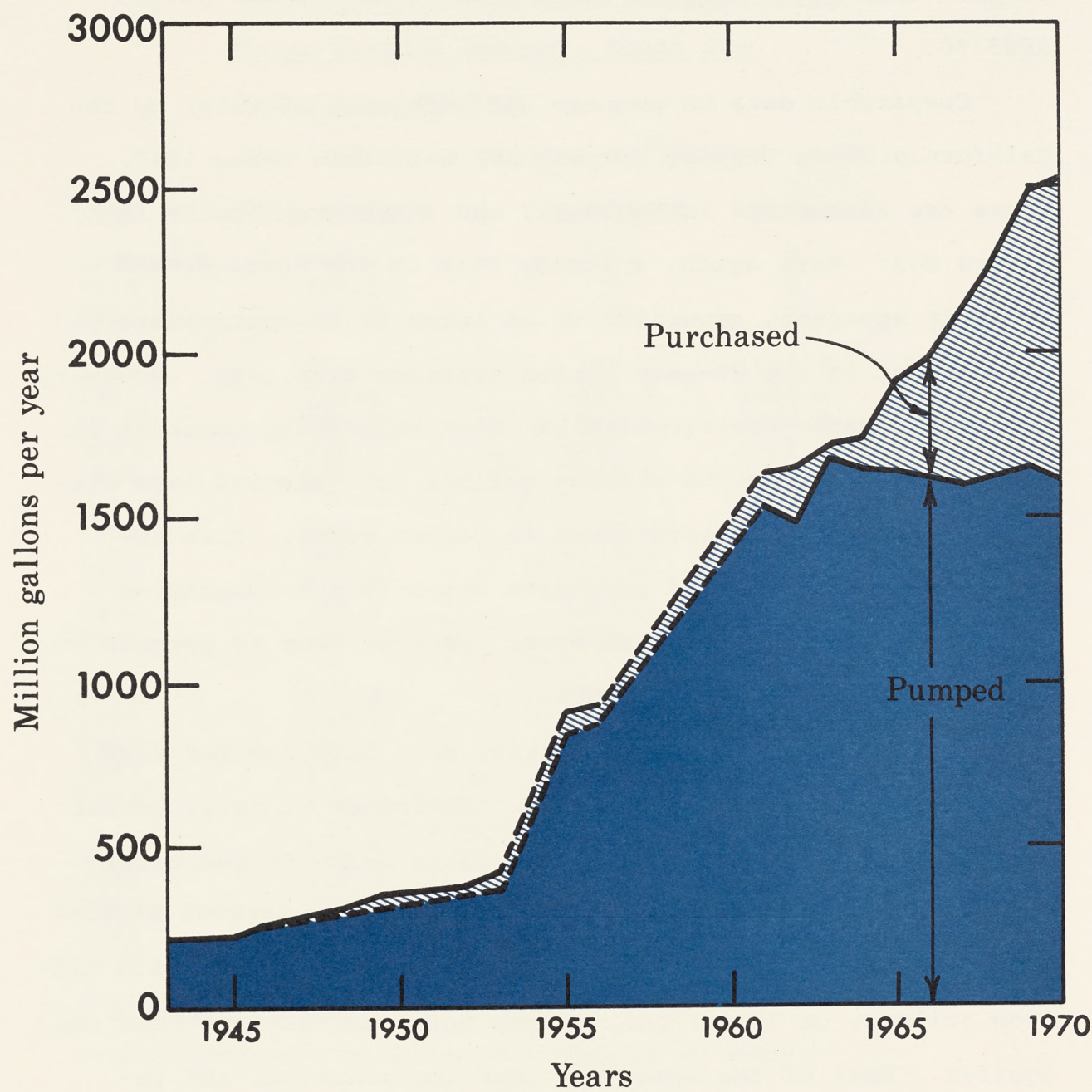


Figure E-1. Annual Volume of Water Pumped and Purchased by the City of Daly City, 1943-70

water pumpage has leveled off, not varying by more than 3 percent from 1,640 million gallons per year for the period 1963-70.

Comparable data on pumpage and purchases of water by the California Water Service Company are available since 1947. These are summarized in Table E-2 and shown graphically in Figure E-2. Here again, a steady rise in the total demand curve is apparent, amounting to an increase of approximately 100 percent in the 20-year period starting with 1950. However, the ground water contribution has been relatively constant in the range of 500 to 750 million gallons per year and even displaying a slight downward trend in recent years. This increasing dependence upon purchased water to meet expanding needs has reduced the ground water fraction from 48 percent in 1950 to only 18 percent in 1969.

Data on pumpage from the entire Daly City aquifer were inventoried as part of this study. Estimates of total annual pumpage for 1969 are summarized in Table E-3. Of the total of 4,510 million gallons pumped, note that the largest single pumper by far is the City of Daly City, which pumped 1,655 million gallons, or 38 percent, of the total extractions from the aquifer. Most of the water was used for municipal and industrial purposes, while the remainder was employed for irrigation of golf courses, cemeteries, and commercial agriculture.

Table E-2. Annual Volumes of Water
Pumped and Purchased by the California
Water Service Company, South San
Francisco, 1947-69

(All values in million gallons per year.)

<u>Year</u>	<u>Well Pumpage</u>	<u>Purchased</u>	<u>Total</u>
1947	708.4	M*	M
1948	725.5	M	M
1949	646.2	M	M
1950	731.1	799.7	1530.8
1951	732.6	917.6	1650.2
1952	743.7	948.6	1692.3
1953	714.7	1068.0	1782.7
1954	680.5	1142.4	1822.9
1955	622.1	1372.8	1994.9
1956	669.6	1412.3	2081.9
1957	703.8	1325.1	2028.9
1958	695.6	1409.1	2104.7
1959	696.7	1615.0	2311.7
1960	689.5	1613.8	2303.3
1961	664.8	1714.5	2379.3
1962	634.2	1680.1	2314.3
1963	677.4	1632.6	2310.0
1964	711.3	1857.6	2568.9
1965	656.9	1993.9	2650.8
1966	620.8	2238.8	2859.6
1967	585.2	2268.6	2853.8
1968	545.5	2322.0	2867.5
1969	529.3	2337.4	2866.7

* M = Data missing.

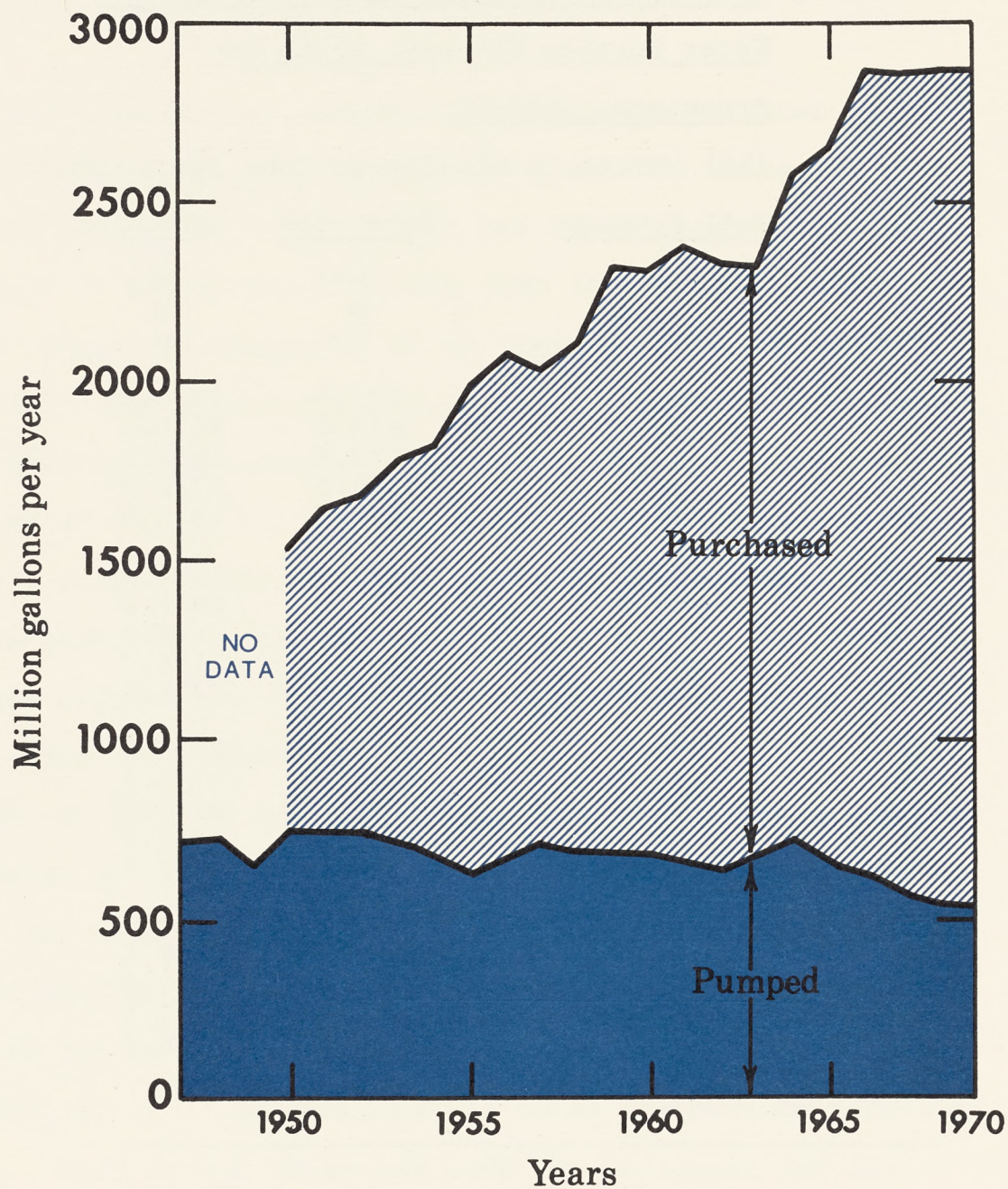


Figure E-2. Annual Volume of Water Pumped and Purchased by the California Water Service Company, South San Francisco, 1947-69

Table E-3. Estimated Total Annual
Pumpage from the Daly City Aquifer
for 1969

<u>Water User</u>	<u>Annual Pumpage,</u> <u>Million Gallons</u>	
Domestic Water Services:		
City of Daly City	1654.9	
City of San Bruno	615.8	
California Water		
Service Company	<u>529.2</u>	
Sub-Total		2799.9
Golf Courses:		
Harding Park	63.2	
Olympic Club	302.6	
San Francisco	252.6	
Lake Merced	173.4	
Cypress Hills	0*	
California	<u>157.7</u>	
Sub-Total		949.5
Cemeteries:		
Woodlawn	63.1	
Italian	31.5	
Olivet	173.4	
Salem	6.3	
Greenlawn	63.1	
Home of Peace	25.2	
Serbian	6.3	
Cypress Lawn	141.9	
Holy Cross	<u>157.7</u>	
Sub-Total		668.5
Commercial Agriculture:		
Nurseries and Truck Farms	92.2	
TOTAL	<u>4510.1</u>	

*Water furnished by Olivet Cemetery.

TRENDS IN GROUND WATER LEVELS

To obtain some insight into trends in ground water levels, records of water levels associated with the eight currently operating wells of the City of Daly City were examined. These include (using the common designations): the three Westlake wells, the four Citrus wells, and the one Colma well. The periods of service of these wells are summarized in Figure E-3. Several other wells, abandoned and filled for ten or more years, are not included in Figure E-3.

Static water levels for the eight City wells were available at irregular intervals since about 1943. All individual well measurements are plotted as "dots" on Figure E-4. The result indicates a range of levels which is to be expected for wells in scattered locations and in operation for different numbers of years. In the earliest years the data is most scarce and the range as drawn is least accurate. A value of +14 feet MSL was reported in 1938 at a now abandoned well. Certainly, in the early days, ground water levels stood well above sea level, as indicated by the aquifer cross-sections in Section A of this report.

Besides the range in water levels, Figure E-4 reveals a long and steady decline in the water table. For the 27-year period 1943-70, the water table has fallen an average of 4.0 feet per year; furthermore, in the last ten years the rate has increased to about 6.0 feet per year. Today a majority of the

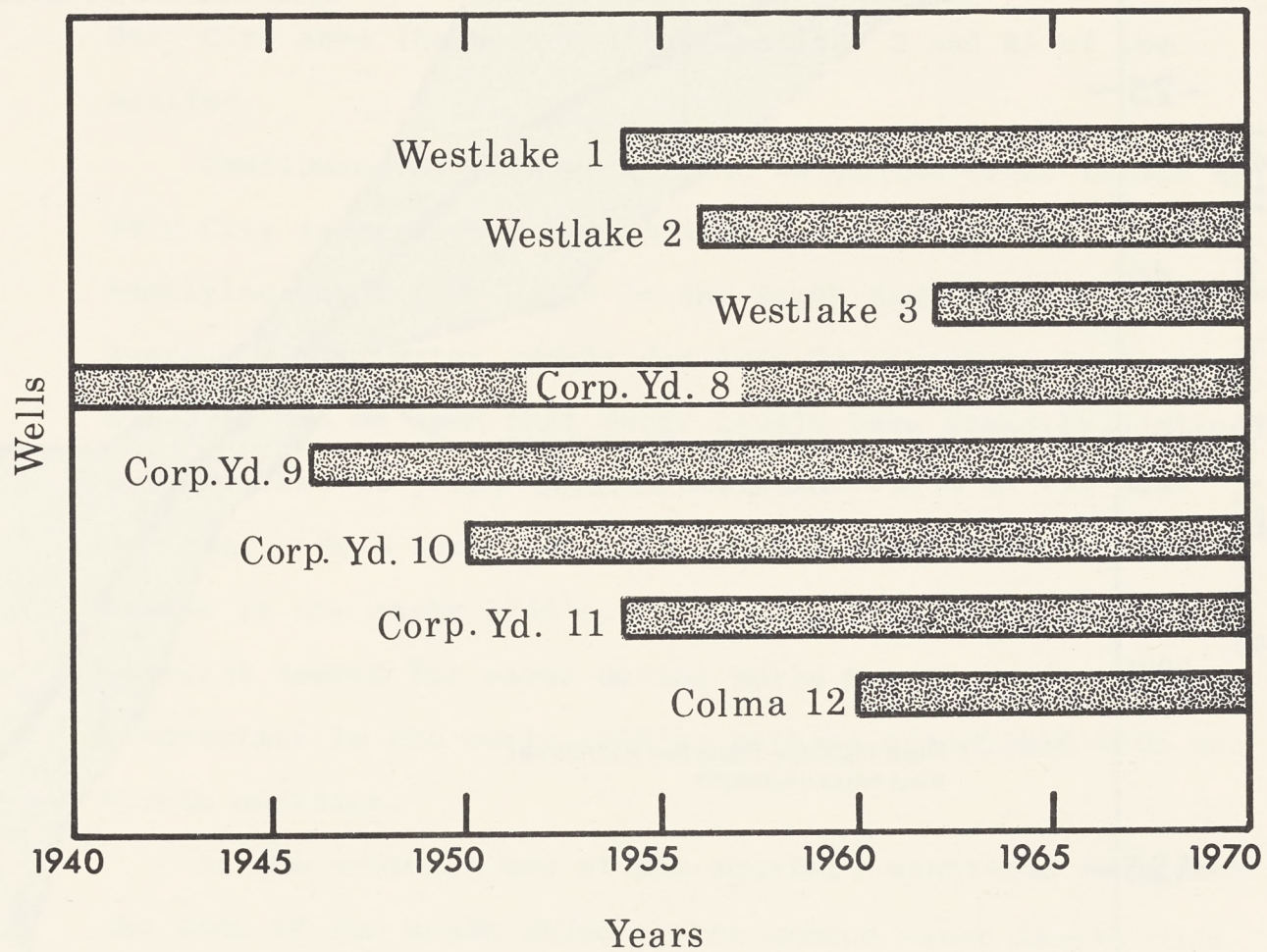


Figure E-3. Periods of Service of
Currently Operating Wells of the
City of Daly City

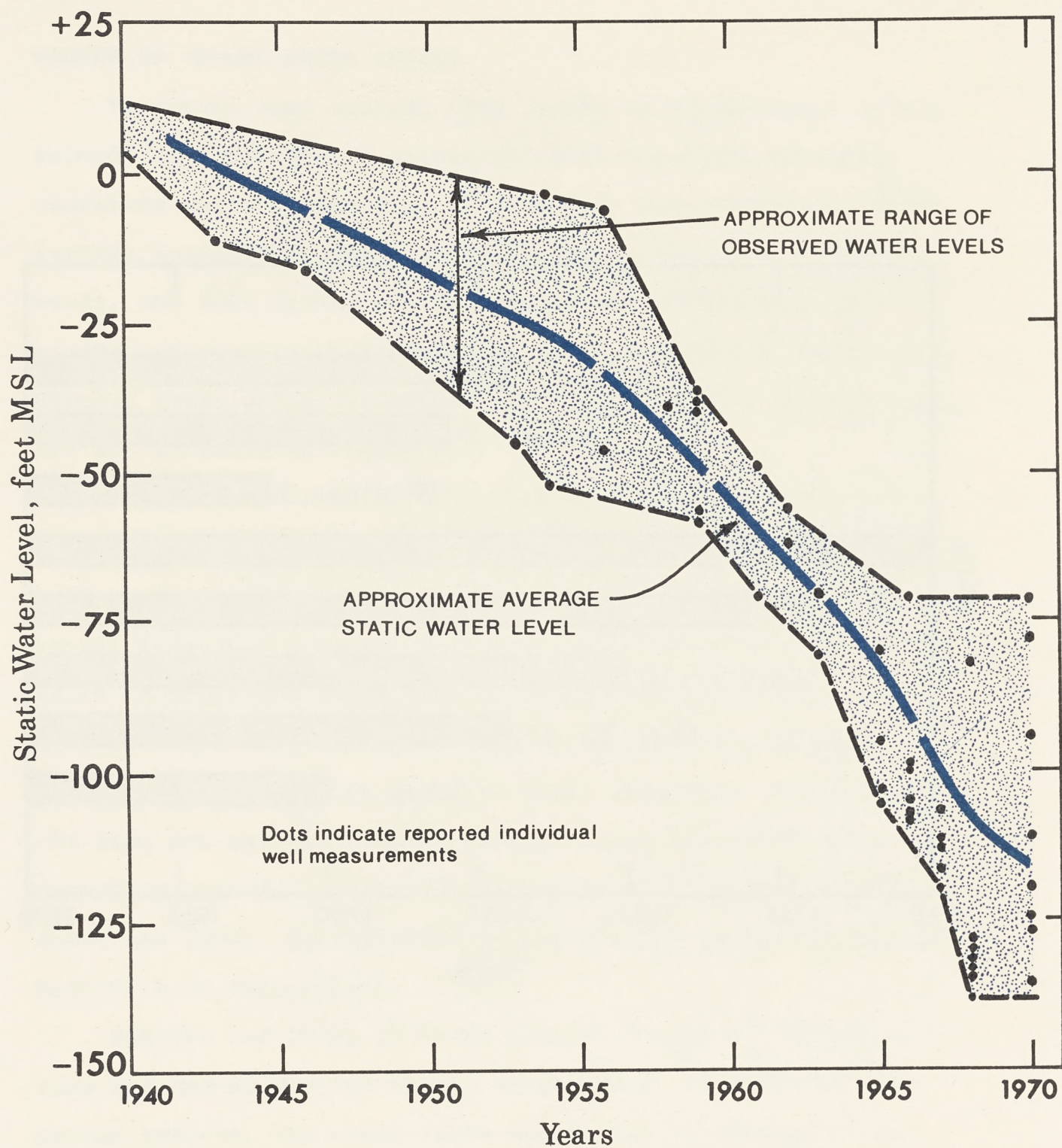


Figure E-4. Changes in Ground Water Levels of City of Daly City Wells During the Period 1940-70.

City wells have static levels more than 100 feet below sea level. This confirms the depletion of aquifer storage reported in Section C of this report, where it was computed that 38 percent of aquifer storage had been dewatered in the Daly City area (between aquifer Sections D and E) of the aquifer.

Confirming the downward trend in ground water levels at Daly City is data from the California Water Service Company, supplying water from wells in the South San Francisco area. Average ground water levels for 1940-70 are shown in Figure E-5. It can be seen that water levels have steadily declined for the last 15 years with an average decline of 2.3 feet per year. Note also the sharp lowering and recovery of levels in the early 1940's, presumably associated with industrial demand for water during World War II, and a similar fluctuation in the early 1950's, perhaps associated with the Korean conflict.

At the southern end of the aquifer, scattered data from the City of San Bruno reveals that ground water levels have also declined. Records for eight wells over the period 1940-55 show an average decline of 5.3 feet per year. That the trend has continued is evident from Figure C-1 which shows that the deepest ground water levels in the entire aquifer are located in San Bruno.

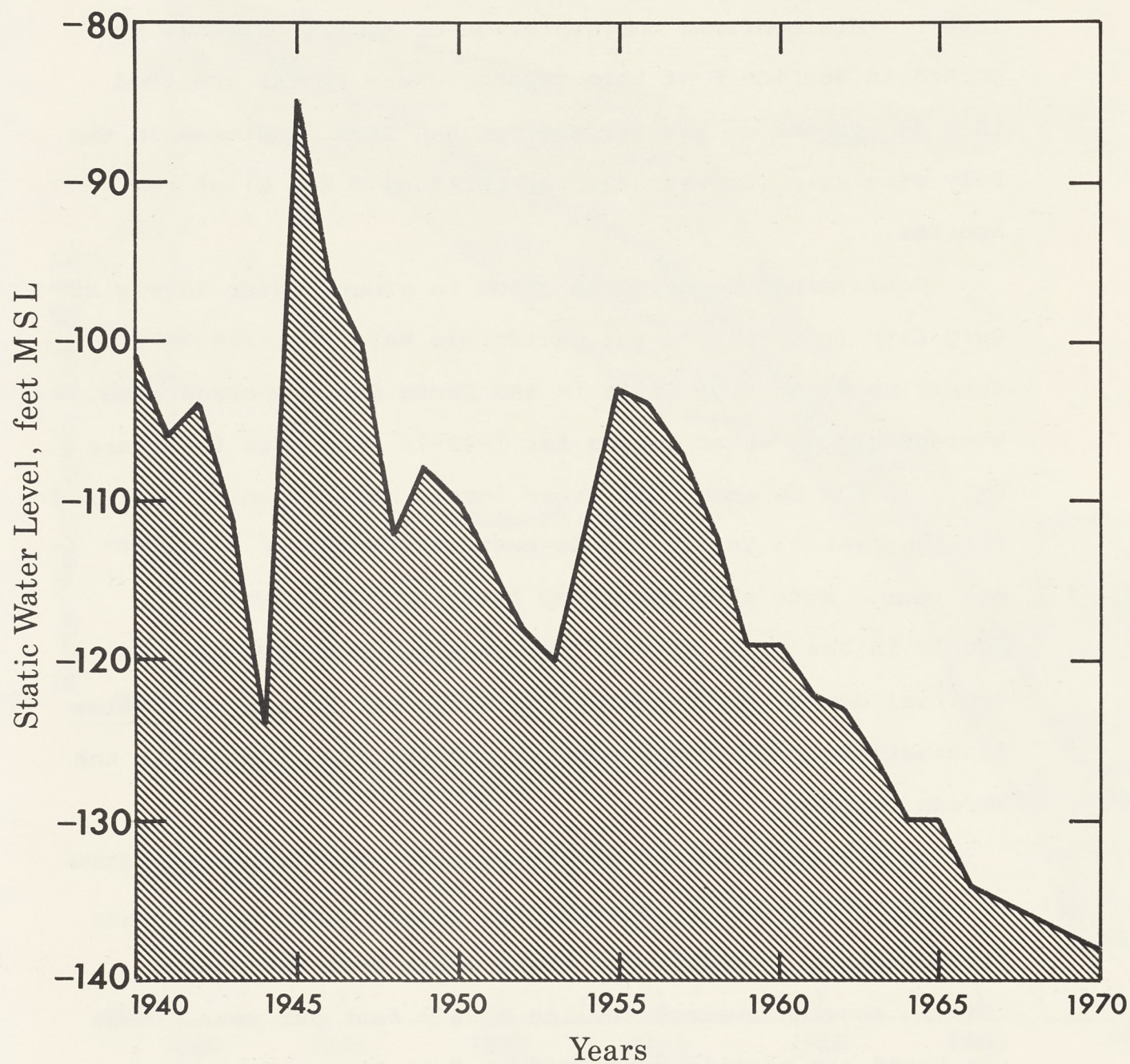


Figure E-5. Average Ground Water Levels
of California Water Service Company
Wells in South San Francisco, 1940-70

SAFE YIELD OF DALY CITY PORTION OF AQUIFER

In Section D it was shown that the estimated mean annual aquifer recharge for the Daly City (and Lake Merced Country Club) wells amounted to 186 million gallons. On a long-time mean basis the safe yield must equal the recharge; therefore, the value of 186 million gallons per year serves as a reasonable estimate of the safe yield for this small portion of the aquifer.

If an aquifer is pumped over a period of years at a rate equal to the safe yield, it can be anticipated that the ground water level will remain approximately stationary. In any individual year variations in rainfall will affect recharge and water levels will fluctuate, but over several years these differences will average out, producing a relatively constant mean ground water level.

Thus, a second method for estimating safe yield is to study the changes in ground water levels with pumpage. If pumpage exceeds safe yield, water levels will fall; if pumpage is less than safe yield, a rise can be expected. With pumpage and ground water level data available, this method can be applied to the Daly City ground water tributary area.

Values of annual pumpage for the Daly City wells for the period 1943-70 were obtained from Table E-1. Missing values were estimated by linear interpolation using Figure E-1. To minimize annual variations mean, annual pumpages for two

consecutive years were computed and are listed in Table E-4.

Table E-4. Changes in Ground Water Levels
and Pumpage of Daly City Wells, 1943-70

<u>Years</u>	<u>Mean Pumpage, Mg/Yr.</u>	<u>Change in Ground Water Level, Ft/Yr.</u>
1943-44	220	-2.5
1945-46	244	-2.5
1947-48	290	-2.5
1949-50	315	-2.5
1951-52	345	-2.5
1953-54	460	-2.5
1955-56	850	-3.7
1957-58	1060	-5.0
1959-60	1330	-5.5
1961-62	1513	-5.5
1963-64	1664	-5.0
1965-66	1627	-7.5
1967-68	1613	-7.5
1969-70	1632	-4.5

Changes in ground water levels were estimated from Figure E-4 using an approximate average static water level with the annual ranges shown. Again, changes for two consecutive years are listed in Table E-4.

The data in Table E-4 are plotted in Figure E-6 which shows changes in ground water levels as a function of pumpage in the Daly City wells for the period 1943-70. This relationship should be recognized as approximate, at best, because of missing pumpage data, estimated ground water level changes, and the absence of historical pumpage data for the Lake Merced Country Club wells. Nevertheless, in spite of these limitations,

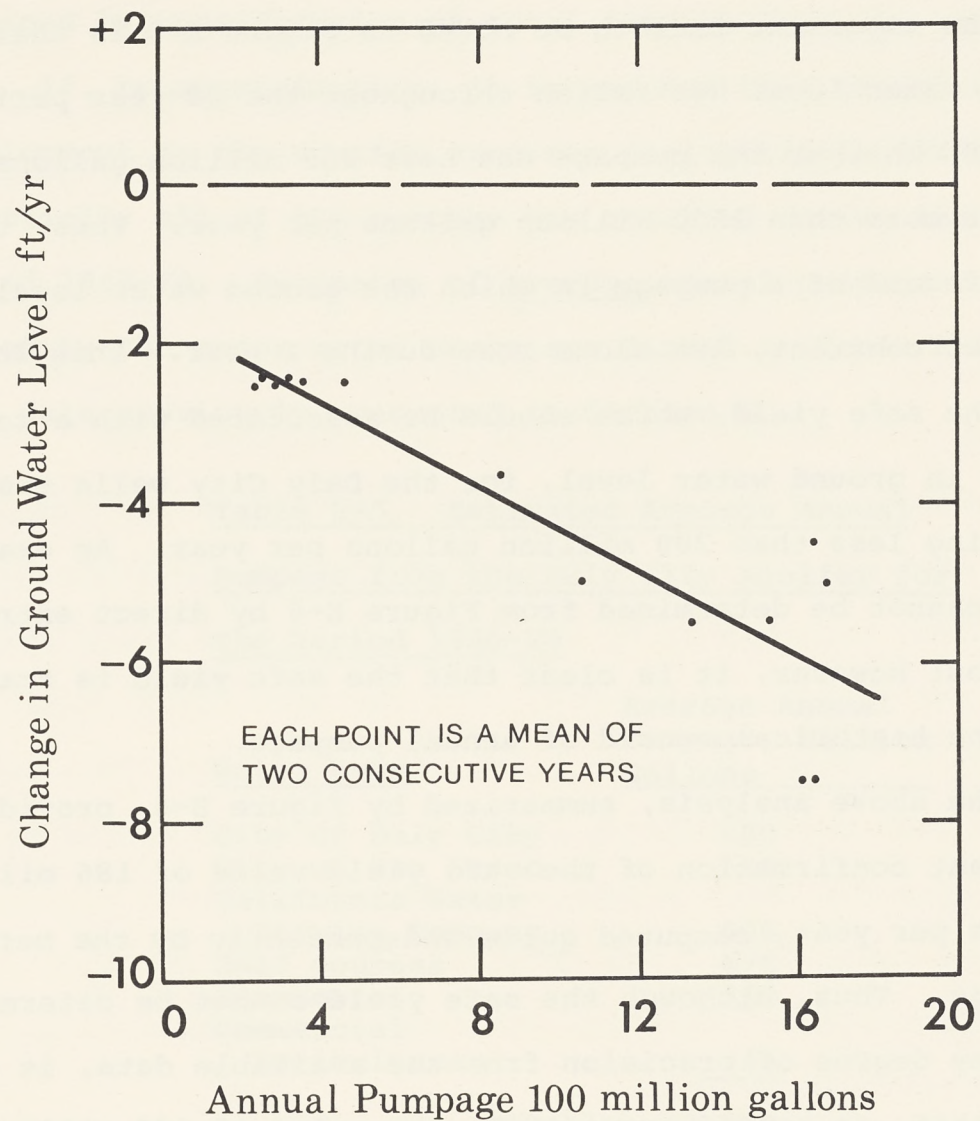


Figure E-6. Changes in Ground Water Levels as a Function of Pumpage in the Daly City Wells, 1943-70

Figure E-6 reveals a well defined trend of increased ground water level lowering with increased pumpage.

The important fact to be noted in Figure E-6 is that the ground water level has fallen throughout the 28-year period 1943-70 whether the pumpage was near 200 million gallons per year or more than 1600 million gallons per year. Thus, there is no record of a pumpage in which the ground water level remained constant, let alone rose during a year. This indicates that the safe yield, which should be associated with a zero change in ground water level, for the Daly City wells must be something less than 200 million gallons per year. An exact value cannot be determined from Figure E-6 by direct extrapolation; however, it is clear that the safe yield is smaller than the historical record of annual pumpage.

The above analysis, summarized by Figure E-6, provides an important confirmation of the safe yield value of 186 million gallons per year, computed quite independently by the method of recharge. Thus, although the safe yield cannot be determined with any degree of precision from the available data, it appears that, as stated previously, the value of 186 million gallons per year is a reasonable estimate of safe yield for the small portion of the aquifer represented by the Daly City ground water tributary area shown in Figure D-4.

SAFE YIELD OF ENTIRE AQUIFER

Some idea of the safe yield of the entire aquifer can be obtained by consideration of total pumpage from the entire aquifer. If, by approximation, it is assumed that ground water development in the aquifer area was negligible in 1940, then essentially all of the pumpage has occurred during the 30-year period 1940-70. Estimates of average annual pumpage for this period by the major water users are listed in Table E-5, based upon data previously presented in Section E.

Table E-5. Estimated Average Annual
Pumpage from the Daly City Aquifer for
the Period 1940-70

<u>Water User</u>	<u>Average Annual Pumpage, Million Gallons</u>
City of Daly City	900
City of San Bruno	500
California Water Service Company	600
Golf Courses	475
Cemeteries	330
Commercial Agriculture	<u>45</u>
TOTAL	2,850

Multiplying the total in Table E-5 by 30 years gives a total extraction of 85,500 million gallons. In Table C-4 it was shown that the total depletion of ground water amounted to 23,900 million gallons. As the aquifer recharge equals the total pumpage minus the total depletion, the recharge amounts

to $85,500 - 23,900 = 61,600$ million gallons. Dividing by 30 years gives an average annual recharge--or safe yield of 2,050 million gallons for the entire Daly City aquifer. This value amounts to 45 percent of the current aquifer pumpage.

Safe yield will vary with the mean recharge to the aquifer. In the future, changes in land use can influence the quantity of water available for recharge. The effect of such changes in the Daly City area on safe yield are discussed in Section G.

OVERDRAFT

By definition, the overdraft of an aquifer is the pumpage in excess of safe yield. The overdraft for the small portion of the aquifer represented by the Daly City ground water tributary area can thus be determined. Let the mean annual pumpage by the City in recent years be 1,640 million gallons (See Table E-1). The Lake Merced Country Club wells are also within this tributary area for which a comparable estimate is 173 million gallons (See Table E-3). The tributary area also contains four abandoned wells. With the previously determined value of safe yield, it follows that:

$$\begin{aligned}\text{Overdraft} &= \text{Pumpage} - \text{Safe Yield} \\ &= (1640 + 173) - 186 \\ &= 1627 \text{ million gallons per year.}\end{aligned}$$

Similarly, the current overdraft for the entire aquifer is $(4,510 - 2,050) = 2,490$ million gallons per year.

These results suggest that current pumpage is far in excess of safe yield. With overdraft occurring, water levels in an

aquifer must steadily decline, producing a steady reduction in the volume of water available in storage. Under these conditions, it can be anticipated that continued pumpage will lead to a gradual depletion of the aquifer and abandonment of many pumping wells.

It should be noted that the last several feet of water in the aquifer cannot be extracted. Some allowance must be made for the drawdown and for the saturated column below the drawdown. Thus, depletion will have been substantially reached when static water levels are above the aquifer bottom, a distance equal to the well's drawdown plus approximately 50 feet.



SECTION F
GROUND WATER QUALITY

WATER QUALITY DATA

From the well summary in Table B-1, water quality data were available for 18 wells belonging to four different organizations. These are listed in Table F-1.

Table F-1. Availability of Ground Water
Quality Data for the Daly City Aquifer

<u>Well Number</u>	<u>Organization</u>
18*	City of Daly City
19	City of Daly City
20	City of Daly City
23	City of Daly City
24	City of Daly City
25	City of Daly City
26	City of Daly City
31	City of Daly City
55	California Water Service Co.
56	California Water Service Co.
57	California Water Service Co.
61	California Water Service Co.
64	California Water Service Co.
59	California Golf Club of San Francisco
60	California Golf Club of San Francisco
72	City of San Bruno
77	City of San Bruno
80	City of San Bruno

*See Figure B-1 for well locations

In order to provide a more extensive areal coverage and to obtain an up-to-date picture of the ground water quality, analyses were made of water samples collected from ten carefully selected wells. The wells were chosen to yield quality data from all representative areas of the Daly City aquifer. The

wells are listed in Table F-2. Samples were collected on February 2, 1971, and were delivered the next day to Brown and Caldwell Laboratories of San Francisco for analysis.

Table F-2. Wells Selected for Water

Quality Sampling in February 1971

<u>Well Number</u>	<u>Organization</u>
10*	Olympic Golf and Country Club
20	City of Daly City
24	City of Daly City
31	City of Daly City
43	Hills of Eternity Cemetery
49	Holy Cross Cemetery
55	California Water Service Company
66	California Water Service Company
69	Avansino-Mortensen & Company
80**	City of San Bruno

*See Figure B-1 for well locations.

**Water sample is a composite of Wells 79, 80, and 82, taken from a sand settling tank receiving water from the three nearby wells.

Although an interpretation of the water quality data is included in this section of the report, it should be noted that all available recent water quality analyses are included in the supporting data furnished the City Engineer. Older data is on file with the organizations listed in Table F-1.

GROUND WATER QUALITY IN 1971

From the complete water quality analyses obtained from the ten wells in February 1971, an abbreviated summary of portions of the data has been prepared and presented in Table F-3. Included are key constituents from the drinking water standards

of the U. S. Public Health Service: chloride, fluoride, iron, manganese, nitrate, sulfate, total dissolved solids, and, in addition, hardness. For comparative purposes the range of values for the three Daly City wells is shown as well as the range for all ten aquifer wells samples. Brief interpretations of the data are contained in the sub-sections which follow Table F-3.

Table F-3. Summary of Selected Constituents from Water Quality Analyses of Daly City Aquifer, February 1971

(All values in milligrams per liter.)

<u>Constituent</u>	<u>Range of 3 Daly City Wells</u>	<u>Range of 10 Aquifer Wells</u>	<u>USPHS Recommended Limits</u>
Chloride	45 - 65	45 - 108	250
Fluoride	0.04 - 0.1	0.04 - 0.26	0.8 - 1.3
Iron	<0.01 - <0.01	<0.01 - <0.01	0.3
Manganese	<0.01 - <0.01	<0.01 - 0.29	0.05
Nitrate	20 - 36	<0.01 - 55	45
Sulfate	9.5 - 28	9.5 - 61	250
Total dissolved solids*	266 - 364	266 - 538	500
Total hardness as CaCO ₃	112 - 189	112 - 288	---

*Mean of calculated and evaporated values by the laboratory.

Chloride. All aquifer values fall well below the U. S. Public Health Service recommended limit of 250 mg/l. Chloride in excess of about 100 mg/l imparts a salty taste to water. Sources are chiefly sedimentary rocks and to a lesser extent igneous rocks.

Fluoride. All aquifer values fall below the U. S. Public Health Service recommended control limits of 0.8 to 1.3 mg/l. Fluoride in these concentrations has a beneficial effect on the structure and resistance to decay of children's teeth. Fluoride in excess of 1.5 mg/l in some areas causes "mottled enamel" in children's teeth, while concentrations in excess of 6.0 mg/l cause pronounced mottling and disfiguration of teeth. Sources are certain metamorphic rocks.

Iron. All aquifer values fall well below the U. S. Public Health Service recommended limit of 0.3 mg/l. More than 0.1 mg/l precipitates after exposure to air; causes turbidity; stains plumbing fixtures, laundry, and cooking utensils; and imparts objectionable tastes and colors to foods and drinks. Natural sources are igneous and sandstone rocks; manmade sources include cast iron and steel in contact with water and industrial wastes.

Manganese. All aquifer values fall well below the U. S. Public Health Service recommended limit of 0.05 mg/l except for Well 10 (Olympic Golf Club) with a value of 0.29 mg/l. More than 0.2 mg/l precipitates upon oxidation; causes undesirable tastes; deposits on foods during cooking; stains plumbing fixtures and laundry; and fosters growths in reservoirs, filters, and distribution systems. Sources are most often soils and sediments; certain metamorphic and sedimentary rocks contain large amounts of manganese.

Nitrate. Only two wells (Hills of Eternity Cemetery and one of the California Water Service Company) exceed the U. S. Public Health Service limit of 45 mg/l. Water containing more than 45 mg/l of nitrate has been reported to cause methemoglobinemia in infants. The Public Health Service states that in areas where the nitrate content of water is known to be in excess of this concentration, the public should be warned of the potential dangers of using the water for infant feeding. Sources are: the atmosphere, legumes, plant debris, animal excrement, nitrogenous fertilizer in soil, and sewage.

Sulfate. All aquifer values fall well below the U. S. Public Health Service recommended limit of 250 mg/l. Sulfate combines with calcium to form an adherent, heat-retarding scale. Sources are oxidation of sulfide ores, gypsum, anhydrite, and industrial wastes.

Total Dissolved Solids. Only two wells (those of the California Water Service Company) exceed the U. S. Public Health Service recommended limit of 500 mg/l. More than 500 mg/l is undesirable for drinking and many industrial uses. Total dissolved solids consist of the sum of the mineral constituents dissolved in water.

Total Hardness as CaCO_3 . Using the hardness classification of the U. S. Geological Survey, the water qualities of the Daly City aquifer show the hardness levels listed on Table F-4.

Table F-4. Hardness Classification of Water Samples

From the Daly City Aquifer Wells

<u>Hardness Name</u>	<u>Total Hardness as CaCO₃, mg/l</u>	<u>Daly City Wells</u>	<u>All Aquifer Wells</u>
Soft	0 - 60	0	0
Moderately hard	61 - 120	1	1
Hard	121 - 180	1	2
Very hard	>180	1	7

Thus, hardness is a basic characteristic of all ground water in the Daly City aquifer. Hardness reduces the sudsing effect of soaps in washing and forms heat-retarding, pipe-clogging scale in boilers and other heat-exchange equipment. Sources are several metamorphic and sedimentary rocks and clay minerals.

GROUND WATER QUALITY OF DALY CITY WELLS

In addition to the February 1971 water quality analyses of three Daly City wells (See Table F-3), analyses were also available for all eight City wells for four recent dates: March and October 1969, and April and November 1970. These analyses appear in the supporting data furnished the City Engineer while a summary of key constituents is presented in Table F-5. Actually, Table F-5 lists the number of wells (of the total of eight City wells) for each of the four analysis dates that exceed specified drinking water standards of the U. S. Public Health Service.

Examination of Table F-5 indicates that the only constituents causing concern are nitrate and phenols. A slight trend of increasing nitrate concentration is evident; however, values actually decreased in two of the three wells analyzed in February 1971. Although the precise cause of these high nitrates cannot be determined, presumably manmade sources of various types are responsible.

Table F-5. Number of Daly City Wells
Exceeding Drinking Water Standards of
the U. S. Public Health Service

(Based on water quality analyses from
8 Daly City wells during 1969 and 1970.)

<u>Constituent</u>	<u>March</u> <u>1969</u>	<u>October</u> <u>1969</u>	<u>April</u> <u>1970</u>	<u>November</u> <u>1970</u>
Chloride	0	0	0	0
Fluoride	0	0	0	0
Iron	1	0	0	0
Manganese	0	0	0	0
Nitrate	1	1	3	3
Phenols	4	3	6	5
Sulfate	0	0	0	0
Total dissolved solids	0	0	0	0

A second ongoing problem for Daly City wells is the presence of phenols exceeding the U. S. Public Health Service recommended limit of 0.001 mg/l. Depending upon the date of analysis, up to three-quarters of the wells show excessive phenols. The February 1971 analyses did not include data on phenols so that no trend in current months can be ascertained. Phenols are organic compounds that affect taste and odor of drinking water. They

originate largely from waste waters of industries such as gas and coke manufacture; synthetic resin manufacture; textiles; tanneries; tar, chemical, and dye manufacture; and sheep-dipping.

In summary, the ground water pumped by Daly City wells and mixed with San Francisco water, as is currently being done, produces drinking water of satisfactory quality. Considering the extensive urbanization in the area, it is doubtful that any new wells drilled by the City would produce water of superior quality to that already being pumped.

It should also be noted that the ground water is somewhat hard; however, this is a characteristic of most California ground waters and thus is not unique to the Daly City aquifer.

SOLVING THE NITRATE PROBLEM

Because the presence of nitrates in concentrations exceeding 45 mg/l constitutes the most important single ground water problem for Daly City wells, attention needs to be given to what can be done as possible solutions. Five alternatives deserve consideration:

1. Treat the water. Treatment for denitrification of water is a costly procedure at best and one that would be difficult to justify economically, particularly because of the borderline levels of nitrate present and because only a few wells are adversely affected.
2. Abandon the wells. Although effective, to replace the local ground water source by water purchased from

the City of San Francisco would be most costly, particularly because ground water costs only about 5 cents/1,000 gallons, whereas water rates of the City of San Francisco, already considerably above the cost of ground water, have recently been substantially increased.

3. Encourage use of bottled water. Nitrates are only important in water used for drinking and for preparing food for babies under six months of age. Thus, if the small quantities of water required for these purposes could be supplied from commercial bottled water sources, the problem would be adequately solved. Although technically feasible, this would require a large public relations investment and would undoubtedly produce a major unfavorable public reaction regarding the dubious quality of Daly City water.
4. Conduct a field investigation. If an extensive series of test holes were drilled throughout the Daly City area and ground water samples were collected and analyzed, a definite map of the distribution of nitrates could be prepared. Although useful, such an endeavor would be extremely costly and difficult to justify economically. Furthermore, the history of the Daly City area suggests that sources such as swampy areas, farms, dairies, cattle feedlots, and septic tanks have contributed nitrates in past decades over

most of present-day Daly City. On this basis, it is doubtful whether any portion of the aquifer in or near Daly City can be expected to be free of nitrates.

5. Dilution. By far the most practical procedure to minimize the nitrate problem is to dilute ground water with imported water having a low nitrate concentration, such as Hetch Hetchy water. The resulting combined water would then be of satisfactory quality with only a relatively minor cost involved.

Finally, it should be noted that the widespread occurrence of well waters in California with nitrate levels exceeding the recommended limit of 45 mg/l has not been shown to produce methemoglobinemia in California residents. The California State Department of Public Health has established administrative procedures for notifications to the public for sources of domestic water exceeding 45 mg/l of nitrates and also exceeding 90 mg/l of nitrates.

SEA WATER INTRUSION

As described in Section C of this report, a potential threat of sea water intrusion into the Daly City aquifer exists, particularly at the southern end from San Francisco Bay. To determine the existing extent, if any, of sea water in pumping wells, the chloride-bicarbonate ratio was computed for the ten well water analyses of February 1971. Results are listed in Table F-6.

The reason for employing the chloride-bicarbonate ratio as

a criterion to evaluate sea water intrusion is because chloride is the dominant ion of sea water and normally occurs in only small amounts in ground water. In contrast, bicarbonate is usually the most abundant negative ion in ground water and occurs in minor amounts in sea water. The ratio is typically less than one for ground water and about 134 for sea water.

Table F-6. Chloride-Bicarbonate Ratios from
Ground Water Quality Sampling in February 1971

<u>Well Number</u>	<u>Cl, mg/l</u> <u>HCO₃, mg/l</u>
10	0.36
20	0.42
24	0.52
31	0.47
43	0.30
49	0.31
55	0.38
66	0.48
69	0.55
80	0.29

Examination of Table F-6 indicates that the ratios are all small and that they do not differ markedly one from the other. Thus, it follows that there is no evidence at present of sea water intrusion in the Daly City aquifer. It should be recognized, nevertheless, that the dynamics of the aquifer reveal that intrusion can be expected at the southern end of the aquifer at some time in the future with continued pumping. There appears to be little probability, however, of this ever having any direct effect on wells operated by Daly City.

SAFE YIELD AND WATER QUALITY

On the basis of the previous discussions, there does not appear to be any water quality limitations at present that would adversely affect the safe yield of ground water supplying the Daly City wells. Moreover, in relation to the serious safe yield limitation imposed by recharge of the aquifer, described in Section E, it can be stated that quantity rather than quality will govern the safe yield of the aquifer both now and in the years immediately ahead.

THE SANDING PROBLEM

One problem reported repeatedly by developers of ground water in the Daly City aquifer is the presence of fine sand in the pumped ground water. The sanding problem is, strictly speaking, not a water quality problem but rather one of improper well design and construction. The size and length of perforations in the well casing, gravel-packing, and well development all have a direct bearing on the potential for a well to produce sand. Some sand is produced from the wells during pumping. However, Daly City solves this problem by removing sand by settling basins at both the Westlake and Citrus Pump Stations. In the case of Well 12, the sand is removed by employing a centrifugal sand removal tank.

Recognizing in the Daly City aquifer that the Colma formation and strata of the Merced formation contain uniform fine sand, it is of utmost importance that any new wells be properly constructed so as to insure that sanding will not become a recurring problem throughout the life of the well. Key factors involved are discussed in the following sub-sections.

Gravel-Packing. In aquifers where fine uniform sand occurs, wells should contain a gravel envelope surrounding the outside of the well in the perforated area. The gravel serves several purposes: 1. It acts to stabilize the natural aquifer formation, preventing possible caving or slumping of the sandy aquifer material. 2. It provides a permeable envelope around the well which permits water to move with minimal resistance from the aquifer to the well. 3. It enables larger perforation sizes to be used in the well casing so that a more efficient well results. 4. It serves as a filter which prevents the movement of sand from the aquifer into the well.

The gravel-pack should be from 4 to 6 inches in thickness in order to insure that the well is completely surrounded. The gravel-pack material should consist of clean, well-rounded, smooth grains; quartz and other silica-based materials are preferable, but limestone and shale are undesirable.

The selection of the grading of gravel-pack material should be such that: 1. its 70 percent retained size is 4 to 6 times the 70 percent retained size of the material in the finest layer

of the aquifer, and 2. its uniformity coefficient, defined as the ratio of the 40 percent retained size of the material to its 90 percent retained size, is less than 2.5. The first condition provides that the gravel-pack material is more permeable than the aquifer, while the second assures that losses of the pack material during development work on the well will be minor.

As an example of the above procedure, see Figure F-1. On the left is shown a typical sieve-analysis curve for an aquifer composed of a mixture of medium and coarse sands, producing a good permeability. The ordinate indicates the cumulative percent by weight of retained material, while the abscissa shows the grain size (equivalent to the size of sieve opening) in thousandths of an inch. The curve on the right represents the analysis of a gravel-pack material which satisfies the above conditions; its 70 percent retained size (0.090 inch) is five times larger than the corresponding size (0.018 inch) of the aquifer material, and the uniformity coefficient is $0.120/0.080 = 1.5$.

In a similar manner for a given sample of aquifer material, various gravels can be checked to see if they will effectively serve as gravel-pack materials.

Perforations. The casing perforations or well screen should be designed to permit water to freely enter the well but at the same time to inhibit entry of gravel-pack material. The openings should be manufactured to predetermined specifications

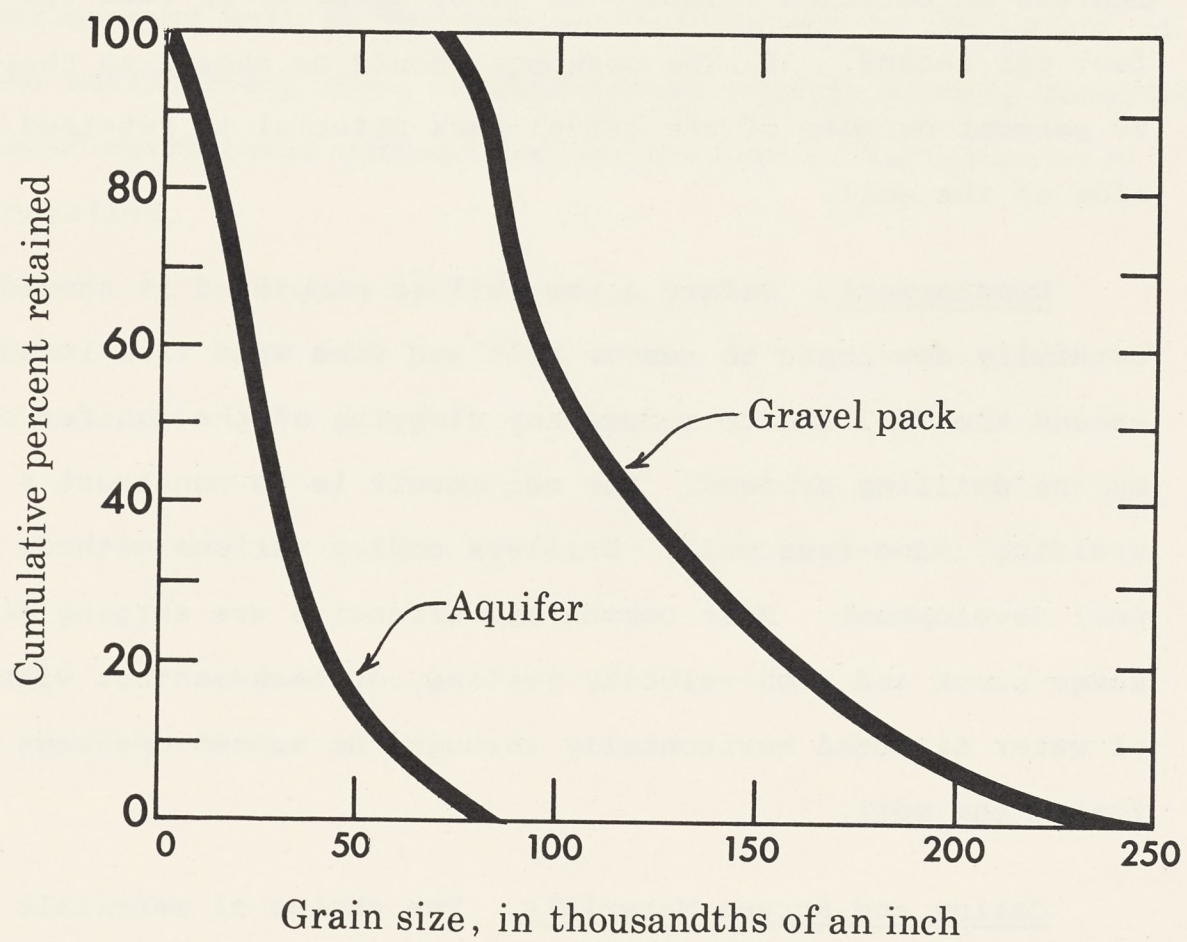


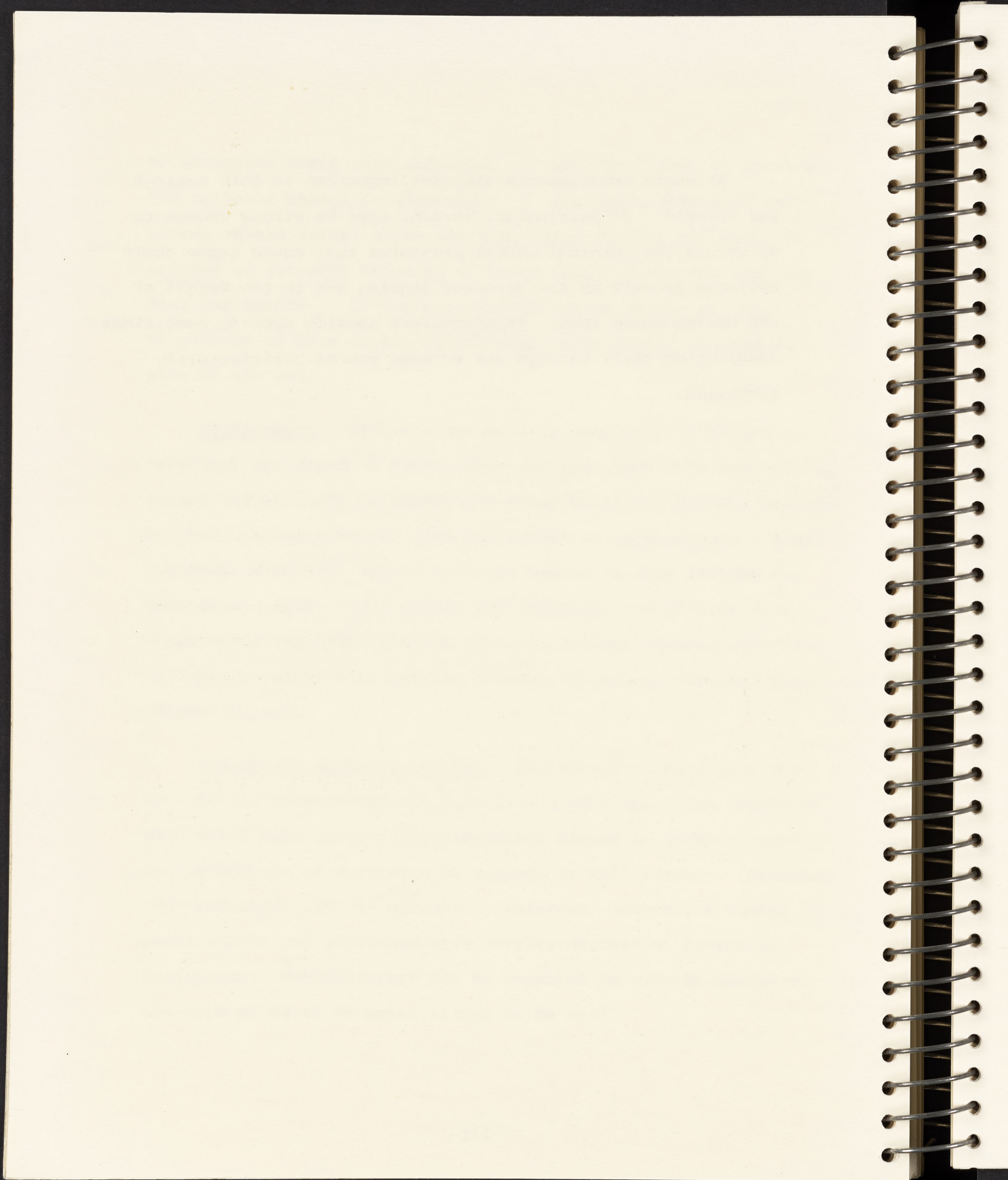
Figure F-1. Sieve-analysis curves for a sandy aquifer and for a gravel-pack material.

to guarantee their size and shape and the total area of openings. Two criteria should be observed: 1. The perforations or well screen should extend along the well for a sufficient length to achieve an entrance velocity of water equal to or less than 0.1 foot per second. 2. The openings should be chosen so that 90 percent or more of the gravel-pack material is retained outside of the well.

Development. Before a new well is completed it should be carefully developed to remove silt and fine sand from immediately around the well and to reduce any clogging of the aquifer created by the drilling process. The net result is to construct a good yielding, sand-free well. Drillers employ various methods for well development. Most common and effective are surging with a surge block and high-velocity jetting, or backwashing, with jets of water directed horizontally through the screen openings from inside the well.

Casing and Screen Materials. The choice of materials that go into the construction of a well is a most important aspect of good water well design. Consideration should be given to minimizing effects of corrosion on casings or well screens. Ordinary iron and steel are not corrosion resistant; however, a number of metal alloys are available with varying degrees of corrosion resistance. Manufacturers can be expected to provide advice on the type of metal or metal alloys to be used.

Strength requirements are also important in both casings and screens. In particular, screens must be strong enough to withstand the external radial pressures that could cause their collapse as well as the vertical loading due to the weight of the casing above them. Manufacturers usually specify conditions under which their casings and screens can be satisfactorily installed.



SECTION G
THE FUTURE GROUND WATER SITUATION

FUTURE LAND DEVELOPMENT

In order to discuss the future ground water situation it is necessary to estimate changes in land development that will occur in the Daly City aquifer area. With increased development the percentage of pervious area decreases so that the recharge available to the aquifer is decreased.

The magnitude of future land development has been determined by reviewing the master plans for land use of Daly City, South San Francisco, San Mateo County, and also the Crocker Estate on San Bruno Mountain. From these, changes anticipated to occur within a 25-year study period, 1970-95, have been evaluated. In turn these changes in land use have been translated into changes in pervious area so that the effect on aquifer recharge could be computed.

The current land use situation, assumed to represent the year 1970, was classified by the categories shown in Table G-1 and the area for each type was planimetered for the entire drainage area of the Daly City aquifer (See Figure D-1), totalling 24.3 square miles, or 15,550 acres. The percentages of pervious area previously assigned (See Table D-7) were then applied to obtain pervious recharge areas for each type of land use. The results, summarized in Table G-1, indicate

that 7,755 acres, or 50 percent of the total area, function as a recharge area.

Table G-1. Land Use Areas Currently (1970)

Contributing Recharge to the Daly City

Aquifer Area

<u>Land Use</u>	<u>Area, Acres</u>	<u>Pervious Area,percent</u>	<u>Pervious Area, Acres</u>
Commercial and Industrial	250	10	25
Residential	9,430	30	2,829
Schools	770	60	462
Cemeteries	710	70	497
Parks	670	75	502
Golf Courses	1,030	85	876
Agricultural	150	90	135
Undeveloped	2,220	95	2,109
Lake Merced	320	100	320
<u>TOTAL</u>	<u>15,550</u>		<u>7,755</u>

The same analysis was conducted for the estimated land use situation in the Daly City aquifer area for the year 1995 at the end of the 25-year study period. The results, summarized in Table G-2, show that 7,131 acres, or 46 percent of the total area, is expected to function as a recharge area.

Table G-2. Land Use Areas Expected
to Contribute Recharge in 1995 to the
Daly City Aquifer Area

<u>Land Use</u>	<u>Area, Acres</u>	<u>Pervious Area, percent</u>	<u>Pervious Area, Acres</u>
Commercial and Industrial	250	10	25
Residential	10,290	30	3,087
Schools	850	60	510
Cemeteries	820	70	574
Parks	720	75	540
Golf Courses	1,030	85	876
Agricultural	150	90	135
Undeveloped	1,120	95	1,064
Lake Merced	320	100	320
TOTAL	15,550		7,131

FUTURE GROUND WATER RECHARGE

Comparing Tables G-1 and G-2, it can be noted that over the 25-year study period a total of 624 acres will be lost as recharge areas to the Daly City aquifer area. This represents a decrease of about 8 percent from the currently available recharge area.

As an approximation, it can be assumed that the relative changes in land use expected over the entire drainage area of the Daly City aquifer apply equally to the Daly City ground water tributary area. If so, the recharge to the Daly City (and also the Lake Merced Country Club) wells will decrease proportionately by 8 percent. On this basis, the safe yield computed in Section E of this report will decrease from 186 million

gallons per year in 1970 to 171 million gallons per year in 1995.

This change in recharge amounts to only a minor fraction of one percent each year; therefore, from a practical standpoint it can be assumed that the ground water recharge and safe yield for the near future--say 5 to 15 years--will remain essentially constant.

FUTURE GROUND WATER EXTRACTIONS

The determination of future water demands in the Daly City aquifer area is beyond the scope of this report. However, from population trends and the projected increase in land development, it is reasonable to expect that total water demand will increase. On the other hand, the rapid increases observed in the last 25 years (See Section E) are not expected to be repeated because of the high degree of urbanization already achieved throughout the area. Given the growth trends in population, land development, and per capita water use, an increase in total water use in the range of 25 to 50 percent during the period 1970-95 should be a reasonable forecast.

With regard to future ground water extractions, it can be expected that total ground water pumpage will gradually decrease and that in relation to total water demand, the ground water contribution will decrease markedly. Interviews with officials of Daly City, San Bruno, and California Water Service Company revealed that there is a widespread awareness of the limited

nature of the existing ground water resources. Although the officials contacted had no quantitative estimates of future ground water availability, they all recognized that the prospects for continued ground water supplies were not encouraging.

Because ground water is the least expensive source of water available in the Daly City aquifer area, water supply officials plan to continue pumping so as to keep purchases of more expensive water to a minimum. In general, a wait-and-see attitude prevails regarding the future availability of ground water.

FUTURE GROUND WATER RESOURCES

Based upon available information, certain statements regarding the future ground water situation in the Daly City aquifer area can be made. Of necessity, future conditions depend upon assumed patterns of recharge and pumping-- basically continuations of those existing at present. In addition, it should be recognized that generalizations about the entire aquifer are difficult if not impossible to make because of the localized concentrations of pumping. Emphasis here will be placed on the Daly City ground water tributary area (See Figure D-4), one small part of the total Daly City aquifer area.

The relative importance and dependence upon ground water in the future is certain to decrease. For Daly City, if total

water demand increases 50 percent in the next 25 years, the relative contribution of ground water, which is presently 64 percent, will become 43 percent if pumpage remains constant. Thus, ground water in the future will become a supplemental source to other major water sources.

With the overdraft now occurring in the aquifer, the total volume of available ground water in storage will continue to decrease in the future. An important point is that a definite limit to the ground water resources can be foreseen. This means that the pumping rate from the aquifer will be sharply curtailed in the next 10 to 15 years, either voluntarily by planned reductions in pumping or involuntarily as wells gradually fail and are abandoned.

More important than the situation for the entire aquifer is what will happen in the small portion represented by the Daly City ground water tributary area (See Figure D-4). If the total pumpage from this area is 1,813 million gallons per year (See Section E) and the safe yield is 186 million gallons per year, then the depletion rate equals the difference, or 1,627 million gallons per year. From data in Section C, the current available ground water volume stored in the Daly City ground water tributary area is computed to be 17,480 million gallons. Dividing this volume by the depletion rate suggests a

remaining aquifer life of about 11 years with pumping continued at its present rate.

A separate means of approaching the same problem is by estimating changes in water levels around the Daly City wells. From the well tabulation in Table B-1, the average bottom elevation of the Daly City wells is -300 feet MSL; the 1971 average static water level is -109 feet MSL; and the average drawdown amounts to 34 feet. Thus, the average available saturated well column equals $300 - 109 - 34 = 157$ feet. Assume that the most recent rate of water level decline, amounting to -7.5 feet per year (See Table E-4), continues and that the wells will essentially go out of production when the drawdown reaches a level at which the saturated well column is only 50 feet long. On this basis the remaining aquifer life is 14 years $(157 - 50)/7.5$, which serves as another estimate of the remaining life of the Daly City wells.

The above estimates of 11 years and 14 years for the Daly City wells are necessarily approximations, based on various assumptions and limited data. Although lacking in refinement, these estimates represent an attempt to indicate quantitatively the remaining ground water resources available to the Daly City wells. As a matter of fact, the life of the wells should be somewhat greater than computed because the rate of depletion in the Daly City ground water tributary area (See Figure D-4) is relatively greater than that for the entire aquifer. This will cause the

tributary area to expand as Daly City ground water levels fall faster than those in adjoining areas, so that a larger proportion of the total aquifer storage will be diverted to the Daly City wells, giving them a limited extension of their productive lives.

Clearly, a foreseeable end to the existing ground water resources is in sight. The reduction in pumping will not occur abruptly but rather over a period of several years. The shallowest or the poorest situated well will gradually fail and be abandoned, followed by others at later dates. Ultimately, with the safe yield only about 10 percent of the current pumpage, instead of ten pumping wells there will be only one or two in continuous operation. Others, perhaps, may be maintained as standby wells for emergency and peaking purposes.

SECTION H

FUTURE COURSES OF ACTION

CONTINUED GROUND WATER DEVELOPMENT

Based upon information presented in the previous section, it can be expected that ground water as a water supply resource in the Daly City aquifer area will be sharply reduced in the years ahead. Whether the reduction in pumpage is done voluntarily or involuntarily, the net result will be basically the same because the safe yield is substantially smaller than current pumpage. The problem will be particularly acute for the City of Daly City because it is by far the major pumper from the aquifer and hence stands to lose the most in terms of available water.

It should be recognized that the drilling of new wells will not aid in solving the coming shortage of ground water. New wells, although temporarily supplying additional water, will only hasten the current rate of aquifer depletion. Even so, a larger number of wells, more widely dispersed and each pumping at a lower discharge, will tend to extend the period of aquifer productivity. Such a well arrangement would produce smaller drawdowns and less interference among nearby wells, enabling a greater fraction of the aquifer storage to be removed before wells cease to produce.

Looking ahead, consideration should be given to reducing

pumpage to a value approaching safe yield. There is no reason, however, that ground water cannot continue to provide a small portion of future water demands. Furthermore, most existing wells can be retained to supply water for emergency and peaking purposes.

The remainder of this section is devoted to a review of alternative courses of action which can be taken by the City of Daly City. The selection of a particular course of action will be governed not only by technical considerations but also by economic, social, and political factors. These latter aspects extend beyond the scope of this report; nevertheless, the following material is intended to assist the City in making decisions necessary to meet the future water needs of Daly City.

PURCHASE OF IMPORTED WATER

At the present time, more than one-third of the water supplied by Daly City is purchased from the San Francisco Water Department. This fraction has grown steadily in recent years; therefore, it is not unreasonable to consider expansion of this water source as ground water resources gradually diminish. San Francisco water is readily available from existing water lines and is excellent water of the highest quality. The chief drawback to using this water source is cost. The current price of San Francisco water for a large private user purchasing directly is shown in Table H-1. If purchased by a Water District or

other political subdivision in the quantity now being pumped, the cost would be approximately 22 cents per thousand gallons. For comparison, the cost of ground water is detailed in Table H-2. Thus, it can be seen that the cost of San Francisco water varies from four to eight times that of ground water.

Table H-1. Tabulation of Cost Per Thousand
Gallons of San Francisco Water for Various
Quantities Used Per Month

<u>User</u>	<u>Avg. Monthly Consumption During Summer</u>	<u>San Fran. Water Pro-rated From Annual Use & Cost Using 1970 S.F. W-21 Rate</u>
Kennedy School	600,000 Gal.	40¢
Westlake Park	1,200,000 Gal.	37¢
Home of Peace Cemetery	4,170,000 Gal.	31¢
Lake Merced Golf Course	14,000,000 Gal.	26¢
Holy Cross Cemetery	15,480,000 Gal.	26¢
Olympic Club	30,840,000 Gal.	24¢

Table H-2. Total Annual Cost and Cost Per
Thousand Gallons for Typical Water Well

DESCRIPTION	ESTIMATED CAPITAL COST	ESTIMATED LIFE	CAPITAL* RECOVERY FACTOR	TOTAL ANNUAL COST
Well Hole 550 Feet Deep Gravel-packed and Cased	\$22,000	15 years	0.10296	\$2,265
Well Pump and Column	9,000	7 years	0.17914	1,613
Electrical Equipment and Controls	7,000	7 years	0.17914	1,254
Concrete Pad and Housing	1,000	15 years	0.10296	103
Power Cost for Pump	--	--	--	2,060
Maintenance and Operation	--	--	--	600
TOTAL ANNUAL COST of Typical Well				<u>\$7,895</u>

*Amount to be paid each year at end of each
life year to repay \$1 with interest earning
on unpaid remainder at a rate of 6 percent.

COST PER 1,000 GALLONS:

Total annual amount of water produced by
pumping at 500 gpm for 60 percent of the
year is 158 million gallons per year.

$$\text{Cost} = \frac{\$7,895}{158,000 \text{ thousand gallons}} = \$0.05 \text{ per } 1,000 \text{ gallons}$$

ADJUDICATION OF THE GROUND WATER BASIN

Recognizing that the Daly City aquifer is now heavily over-pumped raises the question whether legal actions should be initiated to manage the entire aquifer. This would involve adjudication of all water rights in the basin, formation of a public district embracing all pumpers, and a regulated reduction of pumping to that approximating the safe yield. Past experience, particularly in Southern California, has indicated that such a procedure is costly and time consuming, requiring extensive legal work and detailed engineering studies. Time may not permit this prior to depletion.

It appears that in the Daly City aquifer the decrease in ground water storage is directly related to the actions of individual major pumpers and only secondarily by the actions of other pumpers. Thus, the aquifer depletion experience by Daly City is largely of its own making. Cutting back of pumping by the California Water Service Company, for example, would have little or no effect on ground water available to Daly City. This situation occurs because the long narrow structure of the aquifer tends to isolate the actions of individual pumpers, thereby minimizing interactions between adjacent pumpers.

In view of this situation, regulation of pumping would be of little real benefit. As stated before, pumping will be cut back in the future whether by regulation or not; consequently, the costs of establishing and operating an administrative unit to manage the aquifer does not appear to justify such an effort.

ARTIFICIAL RECHARGE OF GROUND WATER

Artificial recharge is defined as the augmentation of natural infiltration of water into underground formations by some method of construction, spreading of water, or artificially changing natural conditions. Although a variety of methods have been developed, the use of spreading basins is by far the most common in California.

Construction of recharge works involves capital expenditures for land, access rights-of-way, buildings, site clearing, grading, levees, canals, diversion structures, roads, measuring devices, control valves, conduit, and fences. Data on recharge projects in Santa Clara, Los Angeles, and Orange Counties suggest that unit costs fall in the range of \$0.03 to \$0.12 per 1,000 gallons of water recharged, exclusive of the original cost of the water itself. However, these costs apply to projects initiated 30 to 40 years ago when undeveloped suburban land was available for \$10.00 to \$100.00 per acre. To obtain flat land for an artificial recharge project today in the Daly City area would undoubtedly involve condemnation of urbanized land at costs in the magnitude of over one thousand times greater than mentioned above. This would be for vacant land within the aquifer--a relatively rare commodity. Under ideal conditions a recharge rate approaching 100 million gallons per acre per year could be achieved. On this basis a land area of some 20 acres, purchased at great expense, would be required to compensate for the ground

water overdraft in Daly City alone.

An injection well is also a convenient means of artificially recharging the underground aquifer. The rate of recharge per well is somewhat lower than it would be for pumping the same well. This is because the pumping process normally serves to unclog the aquifer in the vicinity of the well while recharging through the same well tends to do the opposite. Surface water or reclaimed water being recharged would have some turbidity or other sediment which eventually reduces the recharge rate. This requires backflushing (or direct pumping) of the well to restore the recharge rate. Considering the recurring reduced recharge rate, the time lost by backflushing and the volume of water pumped in the backflushing process, it is normal to expect the recharge rate to be one-fourth of the pumping rate. The pumping rate of the wells in the Daly City aquifer area is 200 to 400 gpm. The recharge rate could therefore be expected to be approximately 75 gpm.

The source of the water to be utilized for artificial recharge is extremely important. Two possibilities bear consideration:

1. Local surface water runoff, and
2. Reclaimed wastewater.

Imported water and converted sea water, if available, would be of excellent quality. They are, therefore, not considered as available as sources for recharge. To place these waters

underground would add an unnecessary cost to already expensive water and would tend to reduce the resulting water quality.

Local surface water draining into the Daly City aquifer area is relatively small in volume and available only occasionally from intermittent streamflows; furthermore, there are no good reservoir sites for storing the water available. The largest stream is Colma Creek, but this also carries only limited flows and has the added disadvantages of being located several miles from Daly City and of flowing away from Daly City. This situation is in marked contrast to that of the San Gabriel River in Los Angeles County and of the Santa Ana River in Orange County, where upstream reservoirs store storm runoff and regulate releases of water at rates that can be handled by recharge facilities.

Reclaimed wastewater could be artificially recharged. However, because this water is not of potable quality, its best use (as described subsequently) would be for direct irrigation of cemeteries, golf courses and parks. If so, there would be little point to storing it underground where it would commingle and degrade the natural ground water intended for domestic use.

Tables H-3 and H-4 were prepared to show that artificial recharge, whether utilizing spreading basins or injection wells with either storm water or reclaimed water as the source, is too costly to consider seriously even without considering the above reasoning. Table H-3 shows that the cost of the land only, for the spreading basin method, is 10-1/2 cents per thousand

gallons. If storm water were to be utilized, this cost should be at least doubled because it can only operate during the six months when storm water is available. The water would then have to be pumped out when needed at an additional cost of 5 cents. This makes artificially recharged storm water cost 26 cents per thousand gallons and no costs for other capital expenditures or for operation are included.

Table H-3. Cost of Land Per Thousand Gallons
of Storm Water or Reclaimed Water Artificially
Recharged Utilizing Spreading Basins

	Estimated Capital Cost	Interest	Total Annual Cost
One acre of land	\$175,000 (\$4/S.F.)	6%	\$10,500
At recharge rate of 100 million gallons per acre per year. Cost per 1,000 gallons =			
	$\frac{10,500}{100,000}$	thousand gallons =	\$0.105 per thousand gallons

Reclaimed wastewater will cost at least 20 cents per thousand gallons for treatment and transmission and 5 cents for pumping when needed, making the cost of artificially recharged reclaimed water exceed 35 cents per thousand gallons. Table H-4 shows that the cost of the injection well per thousand gallons of artificially recharged water is approximately \$0.16.

Table H-4. Cost of Injection Well Per Thousand
Gallons of Storm Water or Reclaimed Water
Artificially Recharged

DESCRIPTION	ESTIMATED CAPITAL COST	ESTIMATED LIFE	CAPITAL* RECOVERY FACTOR	TOTAL ANNUAL COST
Well Hole 550 Feet Deep Gravel-packed and Cased	\$22,000	15 years	0.10296	\$2,265
Well Pump and Column	9,000	7 years	0.17914	1,613
Electrical Equipment and Controls	7,000	7 years	0.17914	1,254
Concrete Pad and Housing	1,000	15 years	0.10296	103
Power Cost for Pump	--	--	--	500
Maintenance and Operation				600
TOTAL ANNUAL COST of Typical Injection Well				<u>\$6,335</u>

*Amount to be paid each year at end of each life year to repay \$1 with interest earning on unpaid remainder at a rate of 6 percent.

COST PER 1,000 GALLONS:

Total amount of water injected into aquifer pumping at rate of 75 gpm is 108,000 x 365 = 39,375 thousand gallons

Cost = $\frac{\$6,335}{39,375 \text{ thousand gallons}}$	=	\$0.16 per thousand gallons
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If storm water were to be utilized, this cost should also be at least doubled because this water is available only six months of the year. The water would have to be pumped out when needed at 5 cents. The cost for artificial recharge of storm

water using injection wells would be approximately 37 cents per thousand gallons.

Artificial recharge of reclaimed water using injection wells would be 16 cents for the well, 20 cents for treatment and transmission and 5 cents for repumping, making a total cost of 41 cents per thousand gallons.

Thus, the conclusion reached from the above reasoning is that artificial recharge of ground water is not feasible economically or technically in the Daly City aquifer area.

DESALTING OF SEA WATER

With sea water available at both ends of the Daly City aquifer area, it is logical to consider the possibility of desalting sea water as a supplemental source of water. Today desalination is a recognized source of fresh water; various desalting processes are available, and with improved technology--especially utilizing nuclear power--unit costs are expected to steadily decrease with time.

As of 1968 the number of desalting plants in operation throughout the world totaled 686. More than 90 percent of these, however, were small plants with capacities of less than one million gallons per day. Almost all (98 percent) of the plants employ a distillation process with the multi-stage flash type being the major producer of fresh water. The Office of Saline Water reported a world-wide annual growth rate of 32 percent in municipal use of desalted water during the period 1961-68.

Projecting that the same growth rate continues, municipal use of desalted water will climb from 121 million gallons per day in 1968 to 835 million gallons per day in 1975.

Costs of converting sea water are subject to varying interpretations depending upon assumptions regarding plant size, type of power, date of construction, water source, water use, operation and maintenance costs, etc. Without attempting to analyze cost components, it seems clear that desalting costs will decrease with plant size and with time. Estimates prepared in 1968 by the U. S. Water Resources Council and shown in Table H-5 confirm these trends.

Table H-5. Projections of Seawater
Desalting Costs in the United States

<u>Year</u>	<u>Water Cost in Cents per 1,000 Gallons*</u>			
	<u>1 MGD Plant</u>	<u>10 MGD Plant</u>	<u>100 MGD Plant</u>	<u>1,000 MGD Plant</u>
1970	75	52	--	--
1975	65	45	24	--
1980	--	40	22	13
1985	--	--	20	12
1990	--	--	--	11

*Projections are based on:

- (1) Distillation technology
- (2) 6% Fixed charge rate
- (3) U. S. construction and operation
- (4) Dual purpose plants
- (5) Most favorable energy costs prevailing at a given time.

Assuming that the future needs of Daly City would be best represented by a 10 MGD plant, it appears from the above information that desalting of sea water will not be economically

feasible within at least the next 20 years in comparison to alternative water sources.

WASTEWATER RECLAMATION

The recently completed Wastewater Reclamation Study for North San Mateo County Sanitation District by Kirker, Chapman & Associates indicates that it is economically, socially, and technically feasible to use reclaimed wastewater as a supplemental source of water. The State of California has promulgated regulations for the use of reclaimed wastewater for the "irrigation of golf courses, cemeteries, lawns, parks, playgrounds, freeway landscapes, and landscapes in other areas where the public has access", provided that the water is adequately disinfected and oxidized.

For a 4 million gallon per day plant total costs are calculated to be \$0.23 per 1,000 gallons, which is essentially equal to the cost of water purchased by the largest users from the San Francisco Water Department, but less than that paid by small users because of rate scheduling. With this tradeoff, consideration would need to be given to the possibility of cost increases and of limitations in delivery capabilities in the future. Furthermore, there may be merit in diversifying the sources of water supplied in the Daly City area.

The proposed 4 million gallon per day plant will operate at a 60 percent efficiency on an annual basis, thereby supplying 876 million gallons of water annually. Current ground water

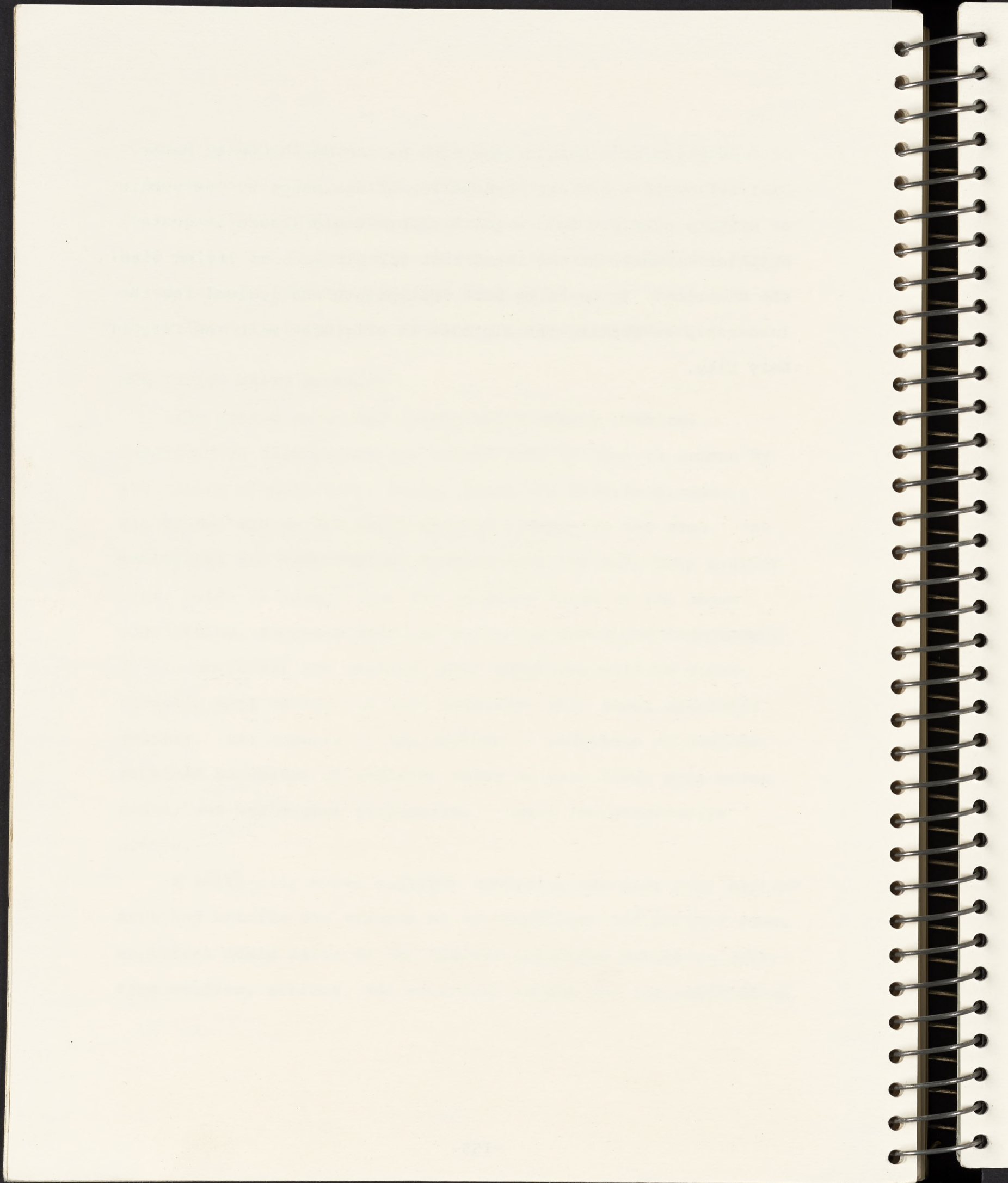
pumpage by golf courses and cemeteries in the Daly City aquifer area (See Table E-3) totals 1,618 million gallons per year. This 4 million gallon per day plant could eventually supply half of the total irrigation needs of the area. Another source of reclaimed water or other substitutional water would have to be found to supply the remaining irrigation demand.

MULTI-CITY WATER DISTRICT

The ground water and future water supply problems described in this report are shared more or less in common by the Cities of Daly City, Colma, South San Francisco, and San Bruno, and by the major private pumpers in the area. The geological and hydrological framework of the Daly City aquifer area, which is larger than the combined areas of the above four cities, suggests that the solutions developed independently by municipal and private water suppliers will be significantly more costly and less effective than those developed jointly. All aspects of the problem -- reduction of pumpage, combined purchases of imported water to gain lower unit water costs, and wastewater reclamation -- call for cooperative action.

A multi-city water district embracing the Daly City aquifer area and uniting the efforts of all municipal and private water suppliers could serve as the logical political entity to undertake studies, actions, and solutions needed for the years ahead.

Adoption of a unique name such as the North County Water District would avoid any connotation of dominance by one public or private agency. Such a joint effort could insure adequate supplies of water at the least cost for all persons living within the district. It would be both appropriate and logical for the leadership in forming the district to originate with the City of Daly City.



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